2013

Working memory capacity training and the effect on reading comprehension, numerical reasoning, and vocational progress

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WORKING MEMORY CAPACITY TRAINING AND THE EFFECT ON READING

COMPREHENSION, NUMERICAL REASONING, AND VOCATIONAL PROGRESS

By

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Dissertation

presented in partial fulfillment of the requirements
for the degree of

Doctorate of Education
in Curriculum and Instruction

The University of Montana
Missoula, MT

December 2013
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UMI Number: 3611868

UMI 3611868

WORKING MEMORY CAPACITY TRAINING AND THE EFFECT ON READING COMPREHENSION, NUMERICAL REASONING, AND VOCATIONAL PROGRESS

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An individual's working memory capacity determines their ability to control attention and discard irrelevant and interfering information in large environments. It also plays an important part in information processing of goal-relevant tasks. It is important to study the ways in which learners can augment the capacity of an important cognitive construct and investigate the potential benefits to improving attention, reasoning, and comprehension. In educational settings, students actively seek help from assistance programs that target academic performance. However, it is often the case that this assistance comes in the form of a targeted specific skill that is focused on a particular academic area. If academic assistance focused rather on overall cognitive ability then there is the potential for a transferring of newly acquired skill to academic achievement scores rather than a specific academic area. Cognitive training in the form of working memory training has shown significant evidence to provide this academic assistance. This single case study used an ABA design to investigate whether working memory training improves performance of adult learners in reading comprehension, numerical reasoning, and vocational progress. The sample was comprised of adults ($N = 10$) within a job core training center who received five weeks of working memory training. The study provided evidence for positive change in measured scores of reading comprehension and numerical reasoning.

Acknowledgments

I would like to acknowledge and thank Kristin and Rory for their love, support, and assistance during the writing of this dissertation.

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CHAPTER ONE

INTRODUCTION

Working memory is a latent construct in psychology that manipulates and updates information in higher-order cognition. Our ability to control attention and discard irrelevant and interfering information in large environments directly relates to our working memory capacity (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005). An individual's working memory plays an important part in information processing of goal-relevant tasks (Engle & Kane, 2004). Despite the heritable forces that go into the creation of an individual's working memory, it is important to study the ways in which learners can augment the capacity of an important cognitive construct. The ability for executive cognitive functions of working memory to expand through intensive training has vast potential to benefit our everyday decision making as well as our attention, reasoning, and comprehension.

Under the theoretical basis of working memory capacity, each person has the ability to store and manipulate information in regard to attention, reasoning, and comprehension based on the level of processing skill of their working memory (Swanson & Howell, 2001). It has also been shown that students who show deficiencies with that same level of processing skill in working memory have difficulty in academic areas (Wendling & Mather, 2009). Working memory's role in the active processes associated with such skills have shown correlations with learning (Schuchardt, 2008), academic achievement (Swanson, 1994), attention deficit disorder (Barkley, 1997), and everyday abilities (Werheid, 2002). The measure of an individual's working memory capacity has become an important indicator of various academic abilities and skills as

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well as a predictor of higher level cognitive processes (Conway et al., 2002). Working memory itself has been seen as a better predictor of academic success than IQ measurements (Alloway, 2010).

In many cases, educators actively seek the establishment of assistance programs that target academic performance. Such a program may include small group instruction, one on one tutoring, or after school help. However, it is often the case that this assistance comes in the form of a targeted specific skill that is focused on a particular academic area. If academic assistance focused rather on overall cognitive ability then there is the potential for a transferring of newly acquired skill to academic achievement scores rather than a specific academic area. Cognitive training in the form of working memory training has shown significant evidence to provide this academic assistance (Morrison & Chen, 2010). However, research in the field or working memory training is still required to show viable transfer gains in fluid intelligence scores. In addition to the need for more research it remains unclear how these gains show specific achievement beyond fluid intelligence assessment scores. Participants in training require multiple assessments of progress that include an evaluation of vocational skills and formal assessments of fluid intelligence.

Statement of the Problem

While studies examining the value of core working memory training programs indicate strong potential for increasing working memory capacity, attention and transfer, there is a general consensus that more studies are needed to determine whether or not there is an actual generalized cognitive enhancement. Moreover, there are few studies that take place outside of controlled lab settings in actual educational settings with students who have a long history of

school failure, or in settings where general academic measures can be compared to measures of vocational skill and knowledge development.

Purpose of the Study

The purpose of this study was to analyze working memory training's enhancement effects and its ability in transferring training task performance to numerical reasoning, reading comprehension, and vocational progress within the realm of standardized testing and facilitator observations. If individuals can actively and successfully train to expand working memory capacity then is numerical reasoning transferred and in what ways can we quantify dynamic changes to numerical reasoning? And in that same respect, if individuals can actively and successfully train to expand working memory capacity then is reading comprehension transferred and in what ways can we quantify dynamic changes to reading comprehension? The study aims to discover the extent to which working memory training impacts participants through formal assessment processes, including measures of academic and vocational progress.

Significance of the Study

It is of significant value in education to study the behavior of working memory capacity because of the strong relationship between a working memory measure and an individual's ability to process information in a goal-relevant task, specifically academic learning. More importantly, individuals with deficits in attention, academic achievement, and cognitive ability can potentially find benefit with an increase working memory capacity.

Theoretical Framework

The first analysis of the structure and function of memory came from the development of a multi-store memory model in 1968. First published by Atkinson and Shiffrin, this model proposed that three structural components had access to control processes in memory such as coding, rehearsal, and search strategies. These three structures known as the sensory register,

short-term store, and long-term store worked together in a unitary system (Atkinson & Shiffrin, 1968). Within this model the flow of information from the sensory register and into the short-term store along with the subject's control of the flow of information are central and intrinsic to the system underling human memory. However, the multi-store model proved to be too simplistic as further research showed many different subcomponents of memory.

A more complex system of short term memory that better represents working memory has replaced the outdated and unitary Atkinson and Shiffrin model. Known as a more multicomponent model, the Baddeley and Hitch model, first published in 1974, developed a system of working memory with its own internal structures and processes. The focus of this model highlights the apparent limit to working memory first discovered by Miller in 1956. Miller's work showed that human memory spans are limited but may be aided by remembering units of information knowing as chunks. Symbolic expressions that chunk information help to enhance memory performance. Baddeley and Hitch studied the limited capacity of memory load by investigating impaired performance of concurrent tasks in reasoning and comprehension. Their investigations yielded the discovery of slave components within the working memory system that carry out concurrent tasks in order to release a central core process for performance of another criterion task. Performance in concurrent tasks would only be impaired if the task required the central core to demand a concurrent memory load to exceed its capacity of its slave component. In other words this central core, known as the executive system, acted to supervise the control and flow of information. This control operates cognitive processes and attention between two slave systems known as the Phonological Loop and the Visuo-spatial Sketchpad (Baddeley & Hitch, 1974). Both slave systems operate independently and the amount of individual attention they receive is dependent upon the cognitive function controlled through the

executive system. The Visuo-spatial Sketchpad works by storing and processing visual and spatial information. The Phonological Loop operates by processing verbal and written information. During an event, for example while driving a car, the Visuo-spatial Sketchpad will process and manipulate information in regards to objects in view and direction. The Phonological Loop will process and manipulate information like concurrent conversations or music from the radio. The executive system must control the slave systems by allowing a driver to focus attention on the most important function, in this case, driving the car. As information is being processed through working memory the multicomponent model helps to understand the complexities of how our brain can focus attention on simultaneous tasks.

The models of working memory have developed over time from studies that have focused on the capacity or limit to an individual's working memory. By analyzing the limits to memory load researchers have learned about the integration of memory systems and individual differences between subjects (Chase & Ericsson, 1982). A model for integration was developed in Cowen's 1995 book that incorporated aspects of the working memory model into long term memory. Cowen argued that working memory and long term memory were not independent systems and that the connection between the two required a simple activation. Therefore, working memory operated both in and outside the focus of a subject's attention (Cowen, 1995). Further studies showed a relationship between long term memory and working memory by arguing that a subject's working memory capacity could actually be enhanced by structures within long term memory. Modern day interpretations of working memory model this construct as a retrieval mechanism of generic, domain knowledge, and episodic text within long term memory (Ericsson and Kintsch, 1995). If a subject has a considerable amount of long term memory on an individual topic and can actively use retrieval techniques they may be able to

enhance their working memory capacity. By studying the capacity of memory researchers could analyze individual differences in working memory. The idea of measuring individual differences allowed researchers to study correlations between working memory capacity and several types of real world cognitive ability.

Newly developed training paradigms have been used widely in the assessment of working memory capacity and the training to enhance performance of working memory. Recent studies in the fluidity of mental processes have shown the benefits of working memory training programs (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). The ability to expand the cognitive processes associated with working memory has large implications in the field of general intelligence and education. If training exercises that target working memory are able to expand information processing (i.e., working memory) then how large of an impact can these dynamic changes affect reasoning, attention, and comprehension within the academic setting?

By using adaptive training of an auditory-verbal and visuo-spatial sequence of core working memory training protocol, Jaeggi et al. (2008) reported positive transfer findings on measures of general fluid intelligence and reasoning. This transfer to fluid intelligence was found through fluid-ability tests and matrix problems. Such a finding may be a direct result of the enhanced ability to store and retrieve important from spatial working memory (Moody, 2009). However, this study did not go beyond generalization to fluid intelligence tasks and did not include further possible implications to other cognitive tests that assess attention, numerical ability, and comprehension. In addition, the study lacked a battery of working memory training protocols and was not complex by only consisting of a single task. More recent studies have addressed this concern by introducing complex training methods and more diverse assessments.

Nature of the Study

An experimental single case research design will be used to better understand the effect of working memory training on the numerical reasoning, reading comprehension, and vocational progress of adults taking a standardized test of basic education. Dynamic changes should be visible within analysis of specific training exercises and benchmark testing scores. If participants are able to transfer gains in working memory capacity to numerical reasoning abilities, reading comprehension, and vocational progress then both working memory and test performance are dependent upon one another.

Research Questions

The research questions are as follows:

1. Does working memory capacity show positive gains with a battery of training exercises over time?

2. If measureable working memory capacity is expanded through comprehensive training exercises, will positive changes occur to reading comprehension via a standard test of adult basic education?

3. If measureable working memory capacity is expanded through comprehensive training exercises, will positive changes occur to numerical reasoning abilities via a standard test of adult basic education?

4. If measureable working memory capacity is expanded through comprehensive training exercises, will positive changes occur to vocational abilities via a facilitator observation of vocational progress monitoring?

The independent variables are pretest working memory training values and posttest working memory training values. These variables will be scored using various training tasks. The

dependent variables include the testing scores of reading comprehension, math computation, and language. In addition, the dependent variables will also be measures of vocational progress. The testing hypotheses are that (a) working memory training will have a positive effect on comprehension and mathematics, and (b) students who complete working memory training will show an increase in their vocational progress.

Definition of Terms

Working Memory. Working memory is a psychological construct first modeled in 1974 in three main components: the central executive system, the phonological loop, and the visuo-spatial sketchpad (Baddeley and Hitch, 1974). The executive system acts as the supervisory system within working memory and controls the flow of information between the other two components. Modern interpretations of working memory model the construct as a retrieval mechanism of generic, domain knowledge, and episodic text within long term memory (Ericsson and Kintsch, 1995). The area of the prefrontal cortex within the human brain allows for this neural mechanism to keep information available for quick retrieval (Smith, 2000).

Working Memory Capacity. Working memory capacity is a measurement of skill developed through prior experience that reflects the ability to engage controlled attention (Kane et al., 2001). It is the ability of individuals in regards to the activation and retrieval of their working memory. Certain individuals can develop this skill, thereby raising their working memory capacity, through deliberate practice (Ericsson, 1996).

Fluid Intelligence. Fluid Intelligence (Gf) is defined as the ability to solve problems through sequential or inductive reasoning without the use of prior knowledge or training on the problem (Horn & Cattell, 1966). It is seen as different to crystallized intelligence (Gc) where knowledge is accumulated over time through experience, training, and formal education.

Test of Adult Basic Education (TABE). The Test of Adult Basic Education (TABE) is a norm referenced standardized diagnostic test used to measure skill and aptitude in reading, math and English. Historically scores of the TABE have been used in public service agencies to assess adult education.

Cognitive training task. Through the development of a cognitive training mechanism, participants undergo working memory capacity training to boost performance on working memory assessments.

Operation Span (OSPAN). The Operation Span Task Assessment (OSPAN) is a working memory training task. In the Operation Span Task (OSPAN) assessment participants will be given lists of mathematical equations and will be asked to respond to the correctness of the formulas (Unsworth, Heitz, Schrock, & Engle, 2005). Participants will solve simple mathematical equations indicating each time whether the solution was true or false, and remember letters presented for 800ms after each math equation for an ordered recall. During this assessment their working memory will maintain lists of letters that participants will be instructed to recall in the order they were presented in ranging from 3-7 pairs. The OSPAN score will be the sum of all correctly recalled sets of letter pairs. This dual task measures storage and processing components of working memory capacity.

Symmetry Span (SSPAN). The Symmetry Span Task Assessment (SSPAN) is a working memory training task. SSPAN task assessment asks participants to look for symmetry in color squares along a 16 square matrix design. Participants must remember the location of random colored squares inside a matrix and remember the order in which they were displayed. Each participant must recall the location of each colored square in order at the end of each trail.

Reading Span (RSPAN). The Reading Span Task Assessment (RSPAN) is a working memory training task. RSPAN is another working memory task assessment where participants must actively follow random sentence patterns and letter locations. Scoring in this working memory assessment is calculated through the participant's ability to recall letter location within the sentence and whether the sentence was phrased in a way that was readable.

Listening Span (LSPAN). The Listening Span Task Assessment (LSPAN) is a working memory training task. In the LSPAN task participants must listen to specific sentences and then simultaneously respond to comprehension questions while remember the last word of each set's sentence. The LSPAN task measures listening comprehension, auditory working memory, and divided attention. The number of correct words recalled is the measure of listening span.

N-Back. The n-back training task is a form of working memory assessment where participants also monitor two simultaneous assessment scenarios (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). First, participants will be asked to follow the location of a square on a computer screen. Second, during the viewing of each square a letter will be read aloud. After a few seconds the location of the square will change on the screen and another letter will be read aloud. After a few rounds of changes, participants will be asked if the box or letter was the same as the box or letter from n rounds ago. The n-back task asks participants to compare a current stimulus to a stimulus presented n trials ago on a continuous basis. For instance, participants in a verbal 2-back task must compare the letter they currently see with the letter displayed two trials ago and determine if the letters are the same or different. The n in the n-back test corresponds to the number of previous rounds since the previous box and letter combination. A participant's n-back score correlates to the number of correctly identified n rounds during the assessment. This computerized test is an adaptive measurement that will increase in difficult over several

successful trails. The n-back task requires individuals to activate and control attention while manipulating their own information processing.

Vocational Progress Monitoring. Using a subjective performance rating of various duties and skills, the Training Achievement Record (TAR) measures vocational progress. Each TAR is tailored to each individual based on desired future employment. Each individual TAR monitors progress on approximately 75 employer specific skills on a performance rating scale.

Summary

The ability for working memory to expand through intensive training has vast potential to benefit our everyday decision making as well as our information processing skills. Adult education facilities that use scores from comprehension and reasoning tests to place individuals for future lines of work can use cognitive training tasks as a way to focus individual attention in testing situations. If participants can use training to control central executive functioning then execution of their abilities will yield higher scores and potentially better cognitive results.

CHAPTER TWO

REVIEW OF THE RELATED LITERATURE

Intelligence and Cognitive Ability

The study and measurement of intelligence begins with the construct of general intellectual ability. By measuring multiple cognitive aptitudes an individual's intellect can be divided into two different components, a crystallized intelligence (Gc) and a fluid intelligence (fc) (Horn & Cattell, 1966). Intellectual ability is both accumulated over time and influenced by biological predispositions (Thompson et al., 2001). Fundamentally, this is what sets apart both measures of intelligence where crystallized knowledge will continue to grow through experience and fluid ability that will stay relatively unchanged throughout life.

One of the most widely accepted modern theories of intelligence is the Cattel-Horn-Carroll Theory of intelligence (CHC) (Cattell, 1941). The CHC states that in addition to intellectual ability, broad abilities of intelligence can be measured through standardized cognitive and academic assessments. These abilities include processing speed, short term memory, long term retrieval, visual processing, fluid reasoning, auditory processing, crystallized knowledge, reading and writing, and quantitative knowledge.

According to Feuerstein's theory of Structural Cognitive Modifiability, intelligence, consisting of various abilities, is malleable through direct instruction of cognitive exercises (Feuerstein & Jensen, 1980). Through intensive training, Feuerstein was able show positive gains in IQ scores through exercises in abstract reasoning, deduction, induction, and spatial tasks (Feuerstein & Jensen, 1980).

Working Memory Models

Understanding the structure and function of human memory requires the formation of memory models that help to explain the complex processes that govern our everyday actions. Beginning with the Atkinson and Shiffrin model in 1968, the modern human memory construct began with a multi-store model containing three structural components that worked together to control the processes in memory. These three structures known as the sensory register, short-term store, and long-term store created a unitary system (Atkinson & Shiffrin, 1968). The flow of information from the sensory register into the short-term store along with the subject's control of the flow of information is central and intrinsic to the system underling human memory.

The multicomponent model, first introduced in 1974, replaced the Atkinson/Shiffrin model by providing a more complex system of short term memory. Known as the Baddeley and Hitch model, its multicomponent nature provided a better understanding of the system of working memory in regards to internal structures and processes The multicomponent model describes the existence of slave components that work concurrently with a central executive that supervises the flow of information. The central executive control operates cognitive processes and attention between the two slave systems that are known as the Phonological Loop and the Visuo-spatial Sketchpad (Baddeley & Hitch, 1974).
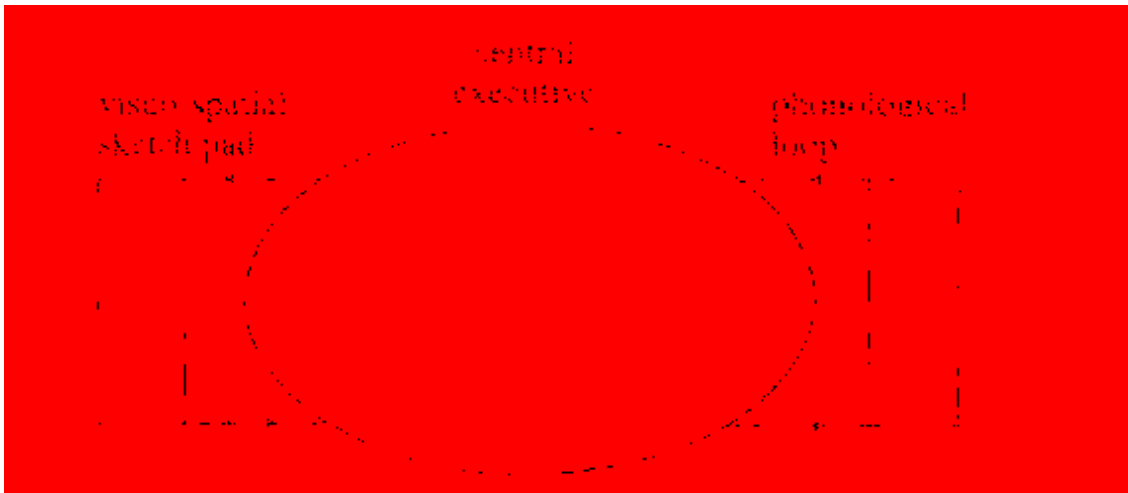
Figure A. The Multicomponent Model (Baddeley, 1974)

The Central Executive and Slave Systems

The executive system controls cognitive function in relation to both slave systems in addition to controlling the amount of individual attention that each system receives. The Visuo-spatial Sketchpad works by storing and processing visual and spatial information. The Phonological Loop operates by processing verbal and written information. In everyday events the Visuo-spatial sketchpad takes in information dealing with visual objections and spatial direction. The Phonological Loop will both simultaneously and independently control incoming information dealing with concurrent conversations and auditory stimuli. It is up to the Central Executive system to control both separate systems and modify the amount of attention required for each to operate. In any situation it is the Central Executive's ability to monitor situations where attention is required. Figure 1 shows the feedback loop of both slave systems that rely on the Central Executive. The multicomponent model gives a good explanation of these complex processes in human attention.
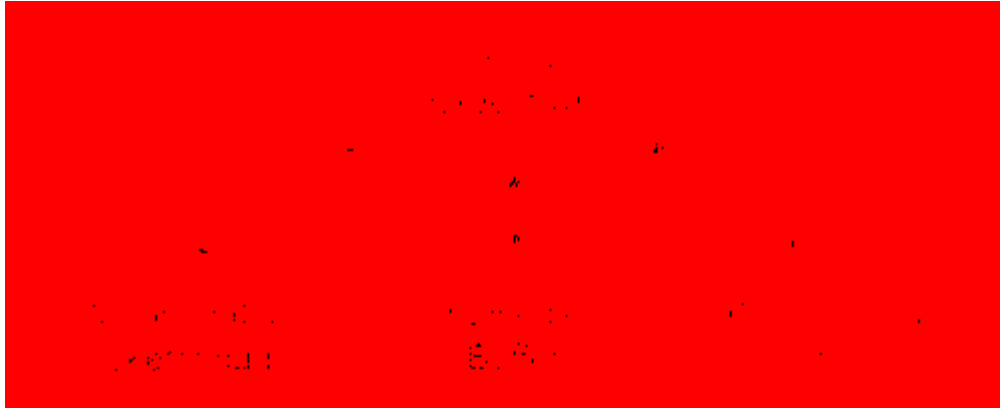
Figure B. The Multicomponent Model with the Phonological Loop (Baddeley, 2002)

The current working memory system model notes the regulation or processes by a central executive component that works with the contents of active memory. Studies of a human's working memory have prompted the functional component that goes beyond just storage and processing of information. The idea of a central control figure was proposed to explain the coordination of two or more slave systems and the deficit in function in patients with Alzheimer's disease. When patients were asked to perform both a visual and verbal task simultaneously there was significant error as compared to similarly aged subjects. However, with tasks that were solely visual in nature or verbal patients did not show the same performance decline (Baddeley, 2002).
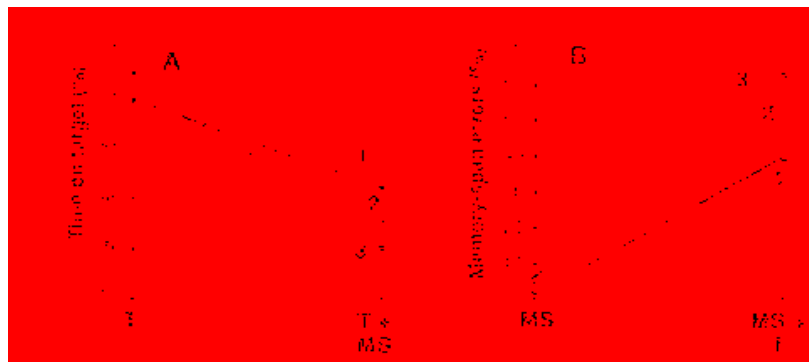
Figure C. Alzheimer's patients Time on Target Vs Single/Dual Tasks and Memory-span

Errors vs. Single/Dual Tasks (Morrison & Chen, 2010)

Figure 3 shows the differences in Alzheimer's patients completing both individual tasks

that use one working memory component as compared to tasks that use both working memory

components. Figure 3 makes the case for the presence of a Central Execute system. In three

different scenarios (1, 2, and 3) patients who worked on tracking tasks alone (T) scored highly.

However, when tracking tasks were added to memory span tasks (MS) scores dropped sharply.

Individual memory span tasks scores showed low occurrence of errors but when paired the

tracking task the amount of errors increased dramatically. Similarly aged subjects did not show a

sharp drop in scores indicating the marked deficit in executive function in Alzheimer's disease

patients (Becker, 1988). Each scenario (1, 2, and 3) indicates the progression of the disease over

time. Individual tasks that rely on one component of working memory held up well over time. It

is the deterioration of the dual task score that indicates the presence of the central executive

(Baddeley, 1986).

In addition to the visual and verbal slave systems, current working memory models

include an additional component known as the episodic buffer (Baddeley, 2000). This

component works with long term memory to transfer events from short term memory in regards

to chronological order and timing. As seen in figure 2, these three components are controlled by

a central executive processing component. By studying all three of these individual slave systems

researchers are able to analyze individual differences in the capacity of working memory. The

idea of measuring individual differences in working memory allows researchers to study

correlations between working memory capacity and several types of real world cognitive ability.

Newly developed training paradigms have been used widely in the assessment of working memory capacity and the training to enhance performance of working memory. Recent studies in the fluidity of mental processes have shown the benefits of working memory training programs (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). The ability to expand the cognitive processes associated with working memory has large implications in the field of general intelligence and education. By using adaptive training of an auditory-verbal and visuo-spatial sequence of core working memory training protocol, Jaeggi et al. (2008) reported positive transfer findings on measures of general fluid intelligence and reasoning. More recent studies have introduced complex training methods and more diverse assessments.

Capacity

Working memory's role in the storing and manipulation of information processing has shown correlations with learning (Schuchardt, 2008), academic achievement (Swanson, 1994), attention deficit disorder (Barkley, 1997), and everyday abilities (Werheid, 2002). Working memory itself has been seen as a better predictor of academic success than IQ measurements (Alloway, 2010). It is of significant value in education to study the behavior of working memory capacity because of the relationship between an individual's ability to process information in a goal-relevant task and academic learning. Newly developed training paradigms have been used widely in the assessment of working memory capacity and the training to enhance performance of working memory. Recent studies in the fluidity of mental processes have shown the benefits of working memory training programs (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). The ability to expand the cognitive processes associated with working memory has large implications in the field of general intelligence and education. In a 2008 study of working memory training, researchers from the University of Michigan correlated the enhancement of working memory training to fluid intelligence by means of a Raven Progressive Matrices Test (Jaeggi,

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Buschkuehl, Jonides, & Perrig, 2008). Participants underwent up to 20 training sessions in 8, 12, 17, or 19 days of training. In this study the n-back task paradigm was used as a method of working memory enhancement. Under the hypothesis that working memory's binding and active attention transferred to reasoning, participants underwent several assessments of fluid intelligence. Each training group showed gains in fluid intelligence compared to control groups. Jaeggi et al.'s 2008 study concluded that:

> Our findings are of general significance because they provide evidence for the enhancement of fluid intelligence by cognitive training different from training the test itself. The finding that cognitive training can improve Gf (fluid intelligence) is a landmark result because this form of intelligence has been claimed to be largely immutable. Instead of regarding Gf as an immutable trait, our data provide evidence that, with appropriate training, there is potential to improve Gf. Moreover, we provide evidence that the amount of Gf-gain critically depends on the amount of training time. Considering the fundamental importance of Gf in everyday life and its predictive power for a large variety of intellectual tasks and professional success, we believe that our findings may be highly relevant to applications in education. (p. 6832)

This finding is significant because previous manipulations in fluid intelligence have often been ambiguous or a result of item based practice (Sternberg, 2008).

Certain varieties of working memory tasks can be used to predict performance on cognitive tasks that have real world applications (Engle, 2002). By recalling items and performing attention demanding tasks, participants' performance can be predicted on a wide range of abilities that include comprehension, ability to follow directions, vocabulary, writing, reasoning, and learning (Engle, 2001). That being said, in studies that compare processing speed

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of working memory tasks to comprehension there must be a control for arithmetic and reading expertise. This is because domain-specific skills do not account for the increase in performance on cognitive tasks when working memory capacity is high (Engle, 2002). It is important to note that greater capacities of working memory yield participants who can manipulate information in a way that maintains appropriate attention while suppressing or avoiding distraction.

Dual Task Training

      The standard model of working memory states that executive functions monitor slave systems that act independently of one another (Baddeley, 2000). As such the measurement of an individual working memory system requires the use of dual task tests. A dual task test requires that subjects complete two different tasks simultaneously. With working memory, a subject should be able to perform a visual/spatial task and a phonological task at the same time with little impairment. By scoring a dual task researchers can get a better picture of an individual's working memory limit than with a simple task. For example, reciting a list of memorized numbers back to a researcher may give them a picture of short term memory capacity, but it does little to tell about a subject's working memory. In a dual task a subject may have to repeat a list of overheard categories back to a research while simultaneously answering mathematical questions. This way a researcher has a better picture of a subject's visual working memory and phonological working memory. And together they can score an individual's working memory capacity. One type of a dual task test is called a span task. In a span task a subject is tested in both their reading and comprehension abilities.

      By using span tasks researchers have found correlations between individuals with high working memory capacities and other cognitive functions. Beginning with Daneman & Carpenter in 1980, the use of span tasks to measure working memory capacity have shown how general cognition is highly predictive of concurrent dual task measures. In the field of reading

and listening comprehension, reading span tasks were used considerably to show relationships of this nature in the 80s and early 90s. Daneman and Carpenter (1980) developed a reading span task to measure working memory capacity in adults. According to their study:

> The reading span task succeeds where previous short-term memory measures have failed. The argument has been that the span task reflects working memory capacity and that this capacity is a crucial source of individual differences in language comprehension. While more promising than previous individual difference analyses, the present studies are still correlational and more evidence will be needed to show precisely how and when working memory capacity limits the comprehension process. (p.463)

In their measure, subjects are presented with sentences and must read each sentence aloud and remember the last word of the sentence for later recall. After a series of sentences the subject is expected to recall all the sentence end words. Daneman and Carpenter's reading span requires categorical storage in addition to processing of sentences. Studies using the reading span task yielded many findings including high correlations between various measures of reading and listening comprehension and working memory capacity (Daneman & Carpenter, 1980, 1983). Measures of working memory capacity during early stages of learning to spell predicted future difficulties in spelling (Ormrod & Cochran, 1988). Subjects with high working memory capacity were capable of following directions better in comparison to simple and complex instructions (Engle, Carullo, and Collins, 1991). Subjects that showed higher in measures of working memory capacity were able to pick up context elements and were better at word associating and vocabulary knowledge (Daneman & Green, 1986). Students' ability to take good notes and perform better on subsequent tests was predicted by working memory capacity measurements (Kiewra & Benton, 1988). Subjects that were rated good writers had better abilities in holding

information in working memory and manipulating information more effectively than poor writers (Benton, Kraft, Glover, and Plake, 1984). The ability to parse and disambiguate ambiguous narrative correlated with working memory capacity (King & Just, 1991). Subjects with better abilities to learning programming through a PASCAL programming course was predicted by working memory tasks (Shute, 1991). All of these research findings used reading and listen comprehension span tasks to measure working memory capacity.

The use of specific span tasks, however, is not seen as a comprehensive measurement of working memory. As research progressed, further studies looked at the link between working memory and intelligence in addition to more rigorous testing methods. Kyllonen & Christal (1990) developed a latent variable analysis in an effort to more efficiently measure working memory capacity and its relationship to intelligence. Their study used a varied content and varied process approach to measuring working memory capacity tasks. Using a wide range of tasks that focus on content and process was essential because no well formulated theories of task requirements in working memory capacity measurements had existed at that time. Their findings showed a strong correlation between working memory capacity and intelligence measures. Also, unlike IQ scales, working memory measurements are less dependent on prior education or experience. In addition, working memory capacity showed a very strong correlation with reasoning ability (r = 0.80-0.90). The Kyllonen & Christal study not only developed a stronger battery of working memory capacity measurements, it also showed the likelihood of working memory capacity to predict performance without the potential for the similar biases of an IQ test. Similar experiments with comprehensive measurements have shown similar correlations between capacity and intelligence (Cantor & Engle, 1993). Using a varied process approach to

measurement further validates the findings and allows researchers to make better analyzed conclusions.

Figure D. Dual N-Back Procedure (Morrison & Chen, 2010)

Training

In the n-back task participants are given simultaneous auditory and visual cues and are asked to store information while processing incoming information. Seen in the figure above, an auditory letter is recited by the program while a visual box is shown on the screen. The participant must note the last time they heard the auditory cue that was the same as the current target in additional to the last time the visual box was located at the same point as the visual target box.

Figure E. Dual N-Back Possible Visual Positions (Morrison & Chen, 2010)

Figure 5, shown above, is an example of the possible visual positions of the box shown at each trail. While viewing one of the eight possible positions, participants will also hear the letter recited for the auditory cute. The "n" in n-back corresponds to how long ago the target cue must match the previous cue. So, for example, in a 2-back seen in the figure the target is currently viewing the box located in the center right position while the auditory target is the letter V. "V" being recited by the program at the same time as the visual target is shown. The participant must correctly note if either the letter is the same or the box is in the same position as it was two trails ago, because this is a 2-back task. In a 3-back task the participant must note if the letter or box position is the same as it was three trails ago. Each step up in an n-back task is progressively more difficult and requires more attention on both visual and auditory fronts. Participants in the Jaegii et al. study received adaptive training where the "n" level would increase as participants become better at the task.

Under the hypothesis that working memory's binding and active attention transferred to reasoning, participants underwent several assessments of fluid intelligence. Each training group showed gains in fluid intelligence compared to control groups (Jaeggi et al., 2008). This finding is significant because previous manipulations in fluid intelligence have often been ambiguous or a result of item based practice (Sternberg, 2008).

A 2011 study investigated working memory training and its ability to improve cognitive function beyond the specific training task (Schweizer, Hampshire, & Dalgleish, 2011). Using similar dual task working memory training researchers found that engagement of executive processes associated with working memory will transfer beyond the task and show gains to fluid intelligence measurements. Their findings suggest that individuals can learn through training on

a task that improves executive control of affective material. When participants became better at engaging with goal-relevant tasks they were able to ignore highly emotional material that was not pertinent or was distracting from the target task.

A 2009 Chinese study of fluid intelligence used a form of n-back task training to improve working memory and intelligence in an adult education setting (Feiyue, Qinqin, Liying, & Lifang, 2009). The study concluded that training tasks associated with excessive memory load (using dual tasks) not only improve task performance but also transfer to fluid intelligence. Through the use of an adult population the study saw highly relevant applications in adult education and significance in intelligence education for adult subjects. The 2009 study concluded that:

> The cognitive training affected the activation in the prefrontal cortex by excessive memory load in dual tasks, and then to improve fluid intelligence. It is different from training the test itself, and performance can remain and transfer. The experiment investigated it is possible to improve fluid intelligence in adults, and this finding is highly relevant to applications in education, therefore the cognitive training system is of great significance in intelligence education of adults. (p.4)

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a task that improves executive control of affective material. When participants became better at engaging with goal-relevant tasks they were able to ignore highly emotional material that was not pertinent or was distracting from the target task.

Training Protocol

The design of working memory training experiments begins with baseline evaluations of cognition. Participants are given computerized samples of working memory assessments to gauge base values of working memory capacity. Using these assessments previous studies have constructed values of latent factors that denote working memory capacity. Participants also undergo ability measurements to gauge a base value of reasoning ability and fluid intelligence. The design of working memory experiments have helped to draw connections between the ability to perform highly on working memory assessments and the ability to score highly on psychometric analyses of higher cognitive reasoning.

Research studies have defined the latent factor of working memory capacity through the use of span tasks assessments, the latent factor of active working memory through the n-back tasks, and the latent factor of fluid intelligence through psychometric indicators. Span tasks, similar to the reading span tasks, are concurrent assignments used to measure a subject's working memory capacity. In the Operation Span Task (OSPAN) assessment participants are given lists of mathematical equations and are asked to respond to the correctness of the formulas (Unsworth, Heitz, Schrock, & Engle, 2005). Participants solve simple mathematical equations indicating each time whether the solution was true or false, and simultaneously remember letters presented for 3 seconds after each math equation for an ordered recall. During this assessment their working memory maintains lists of letters that participants are instructed to recall in the order they were presented in ranging from 3-7 pairs. The OSPAN score is the sum of all

correctly recalled sets of letter pairs. This dual task measures storage and processing components of working memory capacity. The OSPAN score can range from 0-75.

In a Symmetry Span task (SSPAN) assessment participants look for symmetry in color squares along a 16 square matrix design. Participants must remember the location of random colored squares inside a matrix and remember the order in which they were displayed. Each participant must recall the location of each colored square in order at the end of each trail.

In a Reading Span task (RSPAN) assessment participants must actively follow random sentence patterns and letter locations. Scoring in this working memory assessment is calculated through the participant's ability to recall letter location within the sentence and whether the sentence was phrased in a way that was readable. When testing working memory capacity it is important to have a varied battery or span tasks.

The n-back training task is a form of working memory assessment where participants also monitor two simultaneous assessment scenarios (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). First, participants are asked to follow the location of a square on a computer screen. Second, during the viewing of each square a letter will be read aloud. After a few seconds the location of the square will change on the screen and another letter will be read aloud. After a few rounds of changes, participants will be asked if the box or letter was the same as the box or letter from n rounds ago. The n-back task asks participants to compare a current stimulus to a stimulus presented n trials ago on a continuous basis. For instance, participants in a verbal 2-back task must compare the letter they currently see with the letter displayed two trials ago and determine if the letters are the same or different. The n in the n-back test corresponds to the number of previous rounds since the previous box and letter combination. A participant's n-back score correlates to the number of correctly identified n rounds during the assessment. This

computerized test is an adaptive measurement that will increase in difficult over several successful trails. The n-back task requires individuals to activate and control attention while manipulating their own information processing. N-back tasks measure active working memory in addition to help train working memory capacity.

In the design of working memory capacity experiments additional measurements are used to assess fluid intelligence. In a Raven's Advanced Progressive Matrices assessment participants view a 9 pattern matrix of pictures in a sequential pattern. Participants are then asked to select a pattern from choices that would best complete the set of pictures. The Raven assessment is an adaptive test that gains in difficulty over time. Using item response theory a Raven assessment is a measure of general intelligence.

Another example of an assessment used in working memory capacity experiments is the Shipley's Institute of Living Scale. In this test participants complete an abstraction subtest measuring abstract reasoning. The Shipley assessment contains sets in a series of letters, numbers, and works. Participants must complete each series by selecting an item that best follows each set's pattern. By using a comprehensive set of intelligence tests researchers can gain a baseline for comparison in addition to a measure of effectiveness after working memory training is completed.

Academic Implications

The ability to train working memory in an effort to enhance executive function has important implications with individuals with deficits and disabilities in memory and attention. One such study that focused on working memory training targeted children with attention-deficit/hyperactivity disorder (ADHD). In a 2005 study, 53 children with ADHD underwent rigorous working memory training in a double blind study. Both a comparison/control group and

a treatment group received computerized working memory training tasks for a 5 week session. The treatment group received the adaptive training while the comparison/control group received non-adaptive training. As the treatment group progressed through working memory tasks the difficulty increased. This particular study used several different working memory span tasks including a visual span where subjects had to remember order, a backwards digit-span where subjects had to repeat memorized numbers backwards, and a letter span that was spoken to them. Although the small sample size limited generalizability, Klingberg et al.'s 2005 study indicated the following:

> Working memory can be improved by training. In addition, we saw effects on reasoning, response inhibition, and a decreased in parent-rated symptoms of ADHD. The subjects that would be expected to benefit from training of working memory are presumably those individuals for whom executive deficits and inattention problems constitute a bottleneck for everyday functioning or academic performance. These individuals could be found both in the inattentive and combined subgroup of ADHD. It is also possible that training of working memory will be useful in other conditions in which working memory deficits are prominent, such as after traumatic brain injury and stroke affecting the frontal lobe. (p. 185)

The implications of this study along with others dealing with working memory training could be transferable to a considerably large subset of student populations with attention deficits. The development and implementation of computerized working memory training in real world settings would benefit from further research and study.

With the availability and accessibility of technology via the internet the idea of computerized working memory training is a reality. Torkel Klingberg, author of the study on

ADHD and working memory, has introduced an online program called Cogmed. Through the help of a practitioner, students with attention deficits can use the computerized training program to enhance working memory and increase their ability to concentrate. After several decades of research, measurement in working memory capacity has created an applicable use with solid evidence to help subjects in real world cognitive situations. As research in working memory grows so does the amount of empirical findings that show how focused comprehensive and rigorous training can boost working memory capacity and attention.

Changes to Brain Activity

Other recent studies have gone beyond simple pre and post test assessment when analyzing gains to working memory capacity. A 2004 study used functional magnetic resonance imaging to carefully monitor the areas of the brain associated with working memory capacity. It was shown that brain activity related to working memory in the middle frontal gyrus and superior and inferior parietal cortices showed increased activity after a five week training session (Olesen, 2004).

Olesen's study carried out two individual experiments that included five week intensive and adaptive training of three working memory boosting tasks. Similar to other training studies, Olesen found that performance on tasks increased in addition to recall accuracy on trail tasks. Significant training related improvement was found with cognitive control, reading and comprehension, and temporary memory. Both experiments used spatial working memory training tasks that included 20-25 sessions in five weeks.

Everyday Gains in Older Adults

Certain studies have pointed out an inherent problem, however, within the current paradigm of working memory training protocols. Tasks and skills that benefit from working

memory transfer may not be useful to everyday function. Subjects may have shown gains in fluid intelligence, executive functioning, or comprehension but there is no evidence that these same gains transfer to overall attention. And, more importantly, there is little research to show evidence that these gains transfer to older adults, who may benefit more than younger adults (Richmond, 2011).

A 2011 study redirected the focus onto everyday ecological tasks in older adults who underwent working memory exercises (Richmond, 2011). Using working memory span tasks on adults ranging in age from 60-80, Richmond's study followed similar pretest-posttest protocol used with younger adults and found that a complex working memory training regime yielded similar training gains (Richmond, 2011). Richmond's study brought forth evidence that cognitive skills are still malleable in much older cohorts.

In regards to fluid intelligence, Richmond's study found conflicting evidence that working memory training in older adults has the same effect as other previous studies like Jaeggi et al. (2008). Improvements in IQ testing scores through working memory training may require more intensive training due to the difficulty of replication (Chein & Morrison, 2010; Richmond, 2011). Another possible reason for not obtaining positive results with fluid intelligence scores is the small sample size of the study, a common issue with working memory training.

Larger Sample Size

Due to the nature of intense training and long training schedules, working memory studies usually consist of smaller sample sizes. A 2010 study, however, used online cognitive tasks that targeted reasoning, memory, planning, visuospatial skills, and attention to reach a much larger sample size of 11,430 participants (Owen 2010). Given the larger ability to generalize findings, this study is important in the working memory training paradigm. Owen et

al. (2010) was able to show improvement in each individual cognitive task that underwent training. However, there was no conclusive evidence that the battery of working memory training tasks could transfer to other untrained tasks (Owen, 2010).

Much like other working memory studies, participants underwent adaptive training in reasoning tasks, short term memory, spatial memory, and dual task training. Because of the large sample size researchers were able to use a broad battery of tasks that correlate highly with fluid intelligence. Through six weeks of training the study showed no connection between extensive training and improvement in general cognitive functioning (Owen, 2010). Participants placed into the control group who were instead answering general knowledge trivia questions for six weeks showed similar benefits to cognitive function than the experimental group. What sets this study apart from others is the thousands of participants who spent time and effort to undergo training. However, it is also important to point out that, unlike smaller studies, the ability to monitor and proctor training is greatly reduced.

CHAPTER THREE

METHODOLOGY

The purpose of this study was to examine potential measureable gains associated with working memory training. These potential measureable gains include values of working memory capacity, tested values of comprehension, tested values of numerical reasoning, and facilitator evaluations of progressing vocational skills. The Test of Adult Basic Education (TABE) was used to assess numerical reasoning and reading comprehension. If posttest TABE scores are significantly higher than baseline measurements then training can be cause for the improvement. Facilitators will conduct ongoing assessments of vocational skills during training. This progress monitoring will evaluate skills of participants on a more qualitative level. If vocational progress monitoring evaluations are significantly higher than baseline measurements then training can be held accountable for the improvement. This study involved a single case experimental research design with ten participants taking part in a five week treatment of various working memory training tasks. The benefit of a single case research design is that the approach allows for a focus on the evaluations of the intervention phase on specific individuals rather than groups (Barlow, Nock, & Hersen, 2009). Included in this chapter are explanations of the participants, their setting, the design and procedure of the experiment, and the associated data analysis.

Research Questions

The research questions are as follows:

1. Does working memory capacity show positive gains with a battery of training exercises over time?

2. If measureable working memory capacity is expanded through comprehensive training exercises, will positive changes occur to reading comprehension via a standard test of adult basic education?

3. If measureable working memory capacity is expanded through comprehensive training exercises, will positive changes occur to numerical reasoning abilities via a standard test of adult basic education?

4. If measureable working memory capacity is expanded through comprehensive training exercises, will positive changes occur to vocational abilities via a facilitator observation of vocational progress monitoring?

Participants

The population of this study consisted of students enrolled at the Trapper Creek Job Corps Center in Darby, Montana. Study participants will be randomly selected from a list of students who have not passed significant portions of the full TABE at least three times in the last 6 months. Participants range in age from 18-24 and will be enrolled at the job corps center for the entire duration of the experiment. Participants will have the opportunity to opt out of training over the five week training schedule.

Setting

Participants and facilitators will use computer software to receive working memory training task assignments. Each training session will be delivered in summer of 2013 and will be between 50-60 minutes in length. Participants will undergo 15 training sessions under the direction of the software and facilitator assistance. Participants will be given computerized tasks of working memory assessments to gauge values of working memory capacity. Using these assessments the software will construct values of latent factors that denote working memory

capacity. Each week these values will be calculated according to average percent of correctness and average percent of error.

Variables

The independent variables consist of each working memory training task and the associated percent score of correctness and error. The measure of OSPAN, RSPAN, LSPAN, SSPAN, and Dual N-Back was calculated using the computer software and was based on correct responses of individual problems and problem sets in addition to errors of accuracy and speed. The dependent variables consist of scores from the TABE problem sets of reading comprehension and numerical reasoning. In addition to the TAR vocational progress monitoring instrument score.

Instrumentation

Participant mathematical comprehension and reading comprehension was analyzed through archival data of previous TABE scores. Facilitators also have conducted progress monitoring before and after the treatment to assessment vocational skill abilities.

Through the development of a cognitive training mechanism in the training software, experimental participants underwent working memory capacity training in an effort to boost performance on working memory assessments. Participants also completed various sets of working memory capacity training tasks through each training session. Sessions were conducted for a five week schedule with training three times a week. Facilitator evaluations were conducted before the start of the five week training and within a month afterwards. Each assessment instrument is defined as follows.

Operation Span (OSPAN). In the Operation Span Task (OSPAN) assessment participants were given lists of mathematical equations and were asked to respond to the correctness of the formulas (Unsworth, Heitz, Schrock, & Engle, 2005). Participants solved simple mathematical equations indicating each time whether the solution was true or false and remembered letters presented for .8 seconds after each math equation. During this assessment their working memory maintained lists of letters that they were instructed to recall in the order they were presented. The OSPAN score they received was the sum of all correctly recalled sets of letter pairs. This dual task measures storage and processing components of working memory capacity. The OSPAN score can range from 0-75.

Symmetry Span (SSPAN). SSPAN task assessment asks participants to look for symmetry in color squares along a 16 square matrix design. Participants must remember the location of random colored squares inside a matrix and remember the order in which they were displayed. Each participant must recall the location of each colored square in order at the end of each trail.

Reading Span (RSPAN). RSPAN is another working memory task assessment where participants must actively follow random sentence patterns and letter locations. Scoring in this working memory assessment is calculated through the participant's ability to recall letter location within the sentence and whether the sentence was phrased in a way that was readable.

N-Back. The n-back training task is a form of working memory assessment where participants also monitor two simultaneous assessment scenarios (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). First, participants were asked to follow the location of a square on a computer screen. Second, during the viewing of each square a letter was read aloud. After a few seconds the location of the square changed on the screen and another letter was read aloud. After a few rounds of changes, participants were asked if the box or letter was the same as the box or letter

from n rounds ago. The n-back task asks participants to compare a current stimulus to a stimulus presented n trials ago on a continuous basis. For instance, participants in a verbal 2-back task must compare the letter they currently see with the letter displayed two trials ago and determine if the letters are the same or different. The n in the n-back test corresponds to the number of previous rounds since the previous box and letter combination. A participant's n-back score correlates to the number of correctly identified n rounds during the assessment. This computerized test is an adaptive measurement that was increased in difficulty over several successful trails. The n-back task requires individuals to activate and control attention while manipulating their own information processing.

Listening Span (LSPAN). The Listening Span Task Assessment (LSPAN) is a working memory training task. In the LSPAN task participants must listen to specific sentences and then simultaneously respond to comprehension questions while remember the last word of each set's sentence. The LSPAN task measures listening comprehension, auditory working memory, and divided attention. The number of correct words recalled is the measure of listening span.

Training Achievement Record (TAR). This subjective survey was used by job corps supervisors to evaluate each participant's progress throughout the five week training period. Measures of vocational progress calculated by the TAR were assessed on various duties and skills that are job specific to each participant. TAR evaluations were conducted during the baseline phase, treatment phase, and reversal phase.

Research Procedure

Students at the Trapper Creek Job Corps Training Center in Darby, Montana were invited to participate with informed consent collected from the training center principal. All students who were invited had the opportunity to participate in the training but data was only collected from ten randomly selected students. The researcher worked with the principal to identify students who had already sought help for improved scoring on TABE measurements and TAR facilitator evaluations. The research procedure was completed over a five week period.

Pretest Session. Previous scores from TABE values were used to judge ability measurements of cognition. Before the training session, participant TABE scores were used to gauge baseline measurements of mathematics or reading comprehension. Archival data was used from each participant's TABE testing scores and TAR evaluations. Data were taken from a time period ranging from 6-12 months before the start of the first training session to one month of the last training session. Data was gathered from participants with assistance from the job corps. Most participants had completed at least thirty individual mathematic or reading TABE testing sets before the working memory training program. These TABE scores were used to create a baseline measurement of ability.

Training Session. Each participant was seated at an individual computer and the experiment facilitator was present at all times during each session. The training session ranged from 50-60 minutes and was under the guidance of a trained facilitator. Training sessions occurred on a scheduled basis at individual computer stations that were free from distractions. Each session was conducted by a facilitator and consisted of a standard battery of working memory training tasks.

The single subject research methodology was selected in order to measure the effects of working memory training interventions on the same person over time (Kazdin, 1982). The experimental single subject design used the ABA Withdrawal design method in order to observe repeated observations of performance and the immediate effects of the training after the five week period. The ABA Withdrawal design method pays close attention to the training effects during and after intervention in order to evaluate the efficacy of the treatment (Kazdin, 1982). This research design involved the comparison of baseline, intervention, and reversal conditions. This single case study featured ten participants where by each participant acted as their own experimental control. The experimental single subject design helped to explore any causative relationship between the independent variables (working memory training) and a dependent variable (numerical reasoning, reading comprehension, and vocational progress).

Baseline Measurement (Archival Data): TABE Testing (Reading and/or Math), Vocational Progress Monitoring
Several Dates From at least 90 Days Before Training

↓

Baseline Measurement: TABE Test (Reading and/or Math), Vocational Progress Monitoring
Within 30 Days Before Training
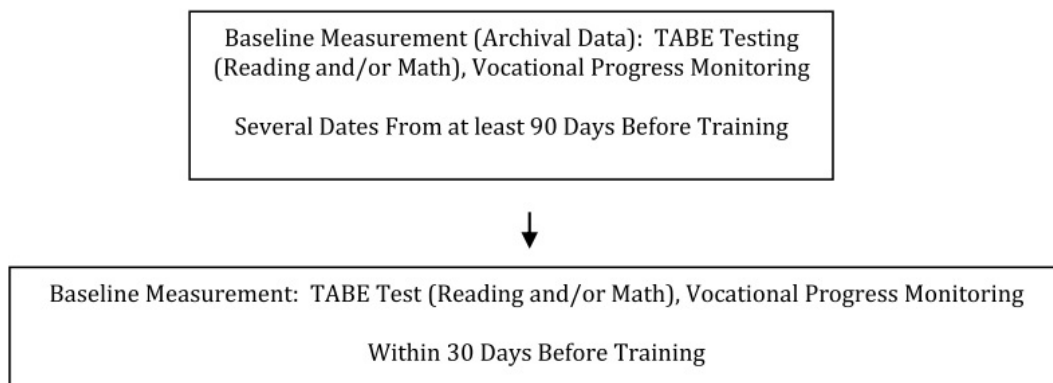
Figure F. Baseline Measurement Research Design

Baseline Measurements. The baseline measurements consist of archival data from TABE mathematics and/or reading scores in addition to TAR vocational progress monitoring

assessments. Data for the baseline measurement was gathered from at least 90 days before

training up to six to twelve months. Data was also gathered from within 30 days before the start

of training.

Training Week #1: Dual N Back Task, Listening Span, Operational Span, Reading Span, Symmetry Span	Treatment Measurement: TABE Scores (Reading and/or Math), Vocational Progress Monitoring
Training Week #2: Dual N Back Task, Listening Span, Operational Span, Reading Span, Symmetry Span	
Training Week #3: Dual N Back Task, Listening Span, Operational Span, Reading Span, Symmetry Span	Within Treatment Time
Training Week #4: Dual N Back Task, Listening Span, Operational Span, Reading Span, Symmetry Span	
Training Week #5: Dual N Back Task, Listening Span, Operational Span, Reading Span, Symmetry Span	

Figure G. Intervention Measurement Research Design

Intervention Measurements. Participants underwent working memory training for a five-

week session. Each training session consisted of a battery of working memory training tasks that

took between 50-60 minutes to complete. During the training session, students received a TABE

assessment of mathematics and/or reading that consisted of 15 individual problem sets. In

addition, participants also were evaluated with the TAR vocational progress monitoring

instrument. Both these TABE and TAR assessments took place during the intervention phase of

the experiment.

Follow Up Measurement: TABE Scores (Reading and/or Math), Vocational Progress Monitoring 30-45 Days After Last Training
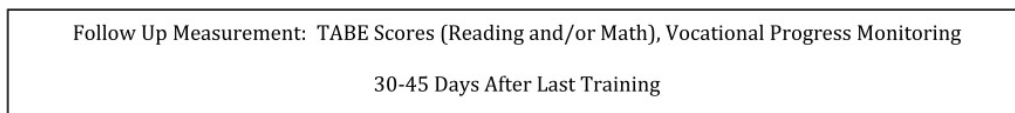
Figure G. Reversal Measurement Research Design

Reversal Measurements. At the conclusion of the five week training session, participants

again received a TABE mathematics and/or reading assessment and a final TAR vocational

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progress mentoring assessment. Both these TABE and TAR assessments took place during the reversal phase of the experiment.

Data Analysis

In order to address all research questions an experimental single case research design was utilized in this study. The effects of the training interventions were assessed using a visual inspection technique. Using a visual inspection technique allows the researcher to evaluate for the effect of an intervention by graphing and visually inspecting the relation between the intervention and the dependent variable of interest (Nock, 2007). This inspection examines behavior across phase conditions by evaluating magnitudes of change in mean, change in trend, and change in variability (Kazdin, 1982). The study defines the latent factor of working memory capacity through the task assessments (OSPAN, SSPAN, RSPAN, LSPAN, N-Back). The analysis investigates the relationships between reading comprehension, vocational progress, and working memory assessments.

The data from the baseline, intervention, and reversal phases were first screened for outliers and then computed for basic descriptive statistics. Changes in working memory performance for each participant was calculated by comparing each performance obtained at the end of each week of training. The data was represented graphically using a simple line graph to show the participants level of performance over time and average scores were stated for each week.

Visual Analysis. A visual examination of data was conducted in order to determine the existence of a relationship between and across baseline, intervention, and reversal phases (Homer, 2005). This visual analysis of intervention effects focused on the examination of level, variability, and trend within the data (Homer, 2005). The level, or the mean or median, was

examined to find the presence of a clear difference between the baseline, intervention, and reversal phases. Level changes are evaluated by examining any significant difference on intervention and reversal phases compared to the baseline. The variability (standard deviation and variance) of each phase was examined to analyze the presence of consistency and control of each phase. A decrease in variability from baseline to intervention or reversal may indicate an influence on a participant's behavior. The trend of each phase was also examined for indications of an increase or decrease in behavior. Visual analysis of data for a single case design should not be the sole method of analysis because of its highly subjective and potentially bias interpretation (Morgan, 2009). However, analysis of level, variability, and trend provide evidence for a functional relationship between variables. In a single case research design, a visual analysis of data is preferred over a statistical analysis (Brossart, Parker, Olson, & Mahadevan, 2006).

Effect Size Analysis. An effect size analysis is a statistical method of examining the extent of the relationship between the independent and dependent variables (Cohen, 1988). Effect sizes provide an indication of the strength of association between the intervention and the measured behavior (Rosnow & Rosenthal, 1989). This can allow for inferences to be made regarding how much the behavior can be explained by the intervention phase. The use of an effect size analysis allows the research to focus on practical significance of the data (Brossart, Parker, Olson, & Mahadevan, 2006). Multiple options for generating effect size measurements exist within a single case design. For this study the effect size was determined using regression methods and a calculated value of R^2.

Regression methods of effect size are based on calculated values of R^2 that interpret an effect as the proportion of variation explained by phase differences (Cohen, 1998). Effect size interpretations are based on categories for large (R^2=.25, medium (R^2=.09), and small (R^2=.01)

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effects. For this study the R^2 statistic was calculated using the least squares regression between TABE and TAR values and intervention.

Assumptions of the Study

The research study assumes that no experimental participant is undergoing additional cognitive training or is taking part in any outside study or scenario that will affect working memory capacity or mathematics and reading comprehension skills. Each training subject will undergo the same equal amount of training in regards to the number of training sessions and the length of each training session.

Limitations of the Study

The research study is limited by the training sessions and sample population of the participants. The study will not take into account a wider range of intensive training that may show more dynamics to the affective processes in working memory. More research in this field can take into account the intensity of training as well as a more generalizable sample size of participants. The study is also limited by the range of ages of the participants and does not take into account the effects of age on working memory.

CHAPTER FOUR

RESULTS

This section contains the findings of the standardized assessments, facilitator observations, and treatment training scores for each individual participant in this study. The primary source of data for this single case design was the assessment data from the Adult Test of Basic Education (TABE) and facilitator observations from the Training Achievement Record (TAR) evaluation. The assessment data from the TABE is divided into either a test of numerical reasoning or a test of reading comprehension. Also included in this chapter is feedback from the working memory training tasks.

Each participant's scores were examined separately using visual analyses. TABE scores were graphed according to their percentage of correct answers on testing sets. TAR scores were graphed according to the total number of vocational proficiencies attained over time. Each participant's working memory training score was graphed according to their correct sets and training errors.

For each individual participant, all TABE scores were examined by level, trend, and variability across sessions. Levels were quantified by comparing the mean scores across each phase. The trend was quantified over the entire experiment by computing the least squares regression. The least squares regression calculation provides effect size data showing the magnitude of relationship between paired quantitative data (Cohen, 1988). The variability of the data was analyzed by computing the standard deviation and variance (σ and σ^2) of each experimental phase.

Additionally, data was collected from facilitator measurements of TAR vocational progress. This data was also graphed and examined through visual analysis of baseline, treatment, and reversal phases. For the TAR data, scores were examined by level across each phase. Levels were quantified by comparing the slope of scores.

The purpose of the current study was to examine the effects of working memory training tasks on the mathematical reasoning, reading comprehension, and vocational progress of job corps students. The study was designed to measure gains in standardized tests of reading comprehension and numerical reasoning. In addition, gains were also measured through facilitator completed evaluations of vocational skills. The data was analyzed using a single subject ABA research design. Baseline data was taken from TABE scores and TAR evaluations to determine a rate of performance for each participant. All participants completed a five-week training in working memory tasks. Data was analyzed and represented separately for each participant.

What follows are a series of figures developed from scores taken during each participant's baseline, treatment, and reversal phases. For the TABE scores, each individual testing session was broken down by subtest. One individual testing session of reading comprehension consisted of five subtests. One individual testing session of numerical reasoning consisted of fifteen subtests. Trend data for the TABE scores was only calculated over the entire experiment because subtest scores of the intervention and reversal phases were a representation of one testing session. Baseline TABE scores consisted of at least three testing sessions over the course of several months. Figure 1 is an example of TABE scores for a participant from the beginning to the end of the experiment. The baseline phase represents three individual TABE tests with five subtests each (fifteen total). The treatment phase represents one individual TABE

test with five subtests. The reversal phase represents one individual TABE test with five subtests. Subtest scores are indicated with a blue line. A trend line is shown in black and individual phase means are represented with a dashed line.
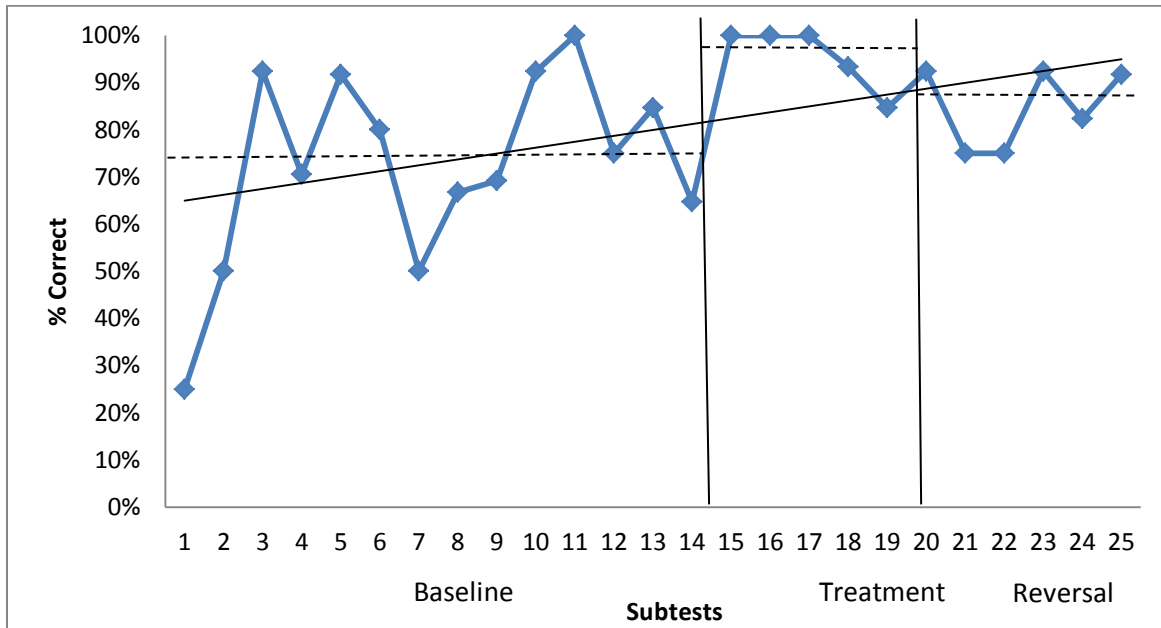
Figure 1. An example figure of correctness on TABE tests during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

TAR scores represent multiple intermittent evaluations over several months of vocational progress. TAR figures increase over time as individual skills are attained and data analysis of trend focuses on changes to slope levels. Working memory training scores represent values of error and correctness. Scores were analyzed to show increased progress of training.

Participant 1

Participant 1was evaluated using the TABE test of reading comprehension and observed using the TAR vocational progress monitoring survey. Participant 1 received five weeks of working memory training during the intervention phase.
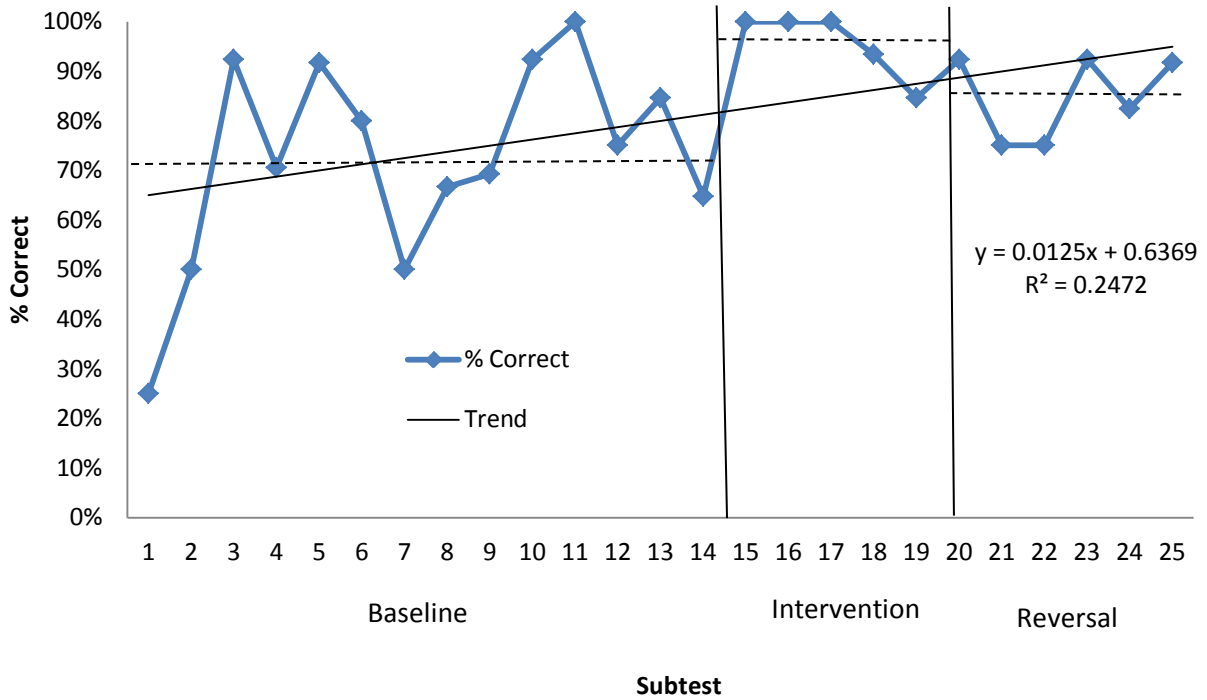
Figure 1.1. Participant 1's correctness on TABE tests of reading comprehension during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

Figure 1.1 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 1.1 provides a graphical representation of the observed TABE scores for participant 1 across all phases of the study. The visual analysis of levels between phases was conducted through examination of each phase's mean. As is evident from the graph, the mean of each phase (shown by the dashed black line) increased over the study. In Phase 1, the mean was 74%; in Phase 2, the mean was 94%, and in Phase 3, the mean was 83%. The increase in mean over time showed that participant 1's percentage of correctness on the TABE exam increased during the intervention phase and overall during the reversal compared to the baseline.

Visual analysis of trend was also conducted by examining the least squares regression. The trend data, shown in Figure 1.1, indicated an upward movement through visual analysis.

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When calculating the least squares regression, a medium relationship ($R^2 = 0.25$) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 1's TABE scores indicated a moderate amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation and variance was calculated to show the dispersion from the average. Participant 1's standard deviation for the entire experiment was 18.5% ($\sigma = .185, \ \sigma^2 = .034$).
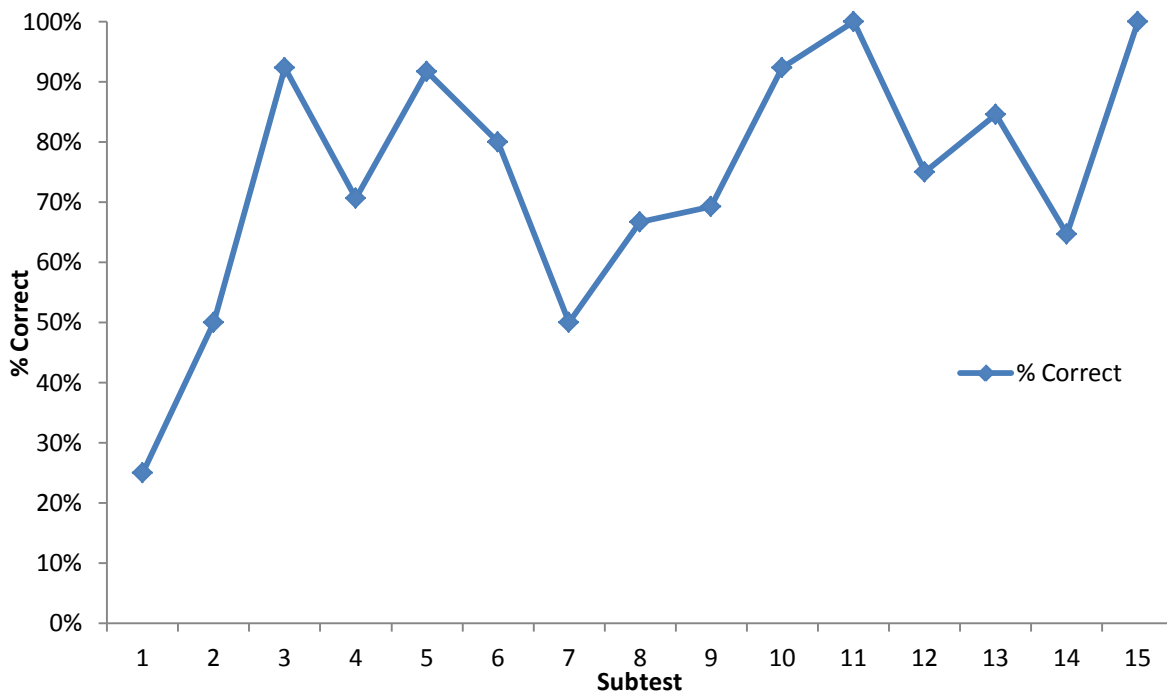
Figure 1.2. Participant 1's correctness trend for the TABE during the baseline phase.

For each individual phase the level and variability are analyzed. Figure 1.2 shows TABE data for the baseline phase. The data points of the baseline phase indicate a large variability and a mean of 74%. The standard deviation of the baseline phase was 21% ($\sigma = .210, \ \sigma^2 = .044$).

Figure 1.3 shows TABE data for the intervention phase. The data points of the intervention phase indicated a low variability and a mean of 94%. The standard deviation of the intervention phase was 6.4% ($\sigma = .064, \ \sigma^2 = .004$).

Figure 1.4 shows TABE data for the reversal phase. The data for the reversal phase indicated a low variability and a mean of 83%. The standard deviation for the reversal phase was 8.5% ($\sigma = .085, \ \sigma^2 = .007$).
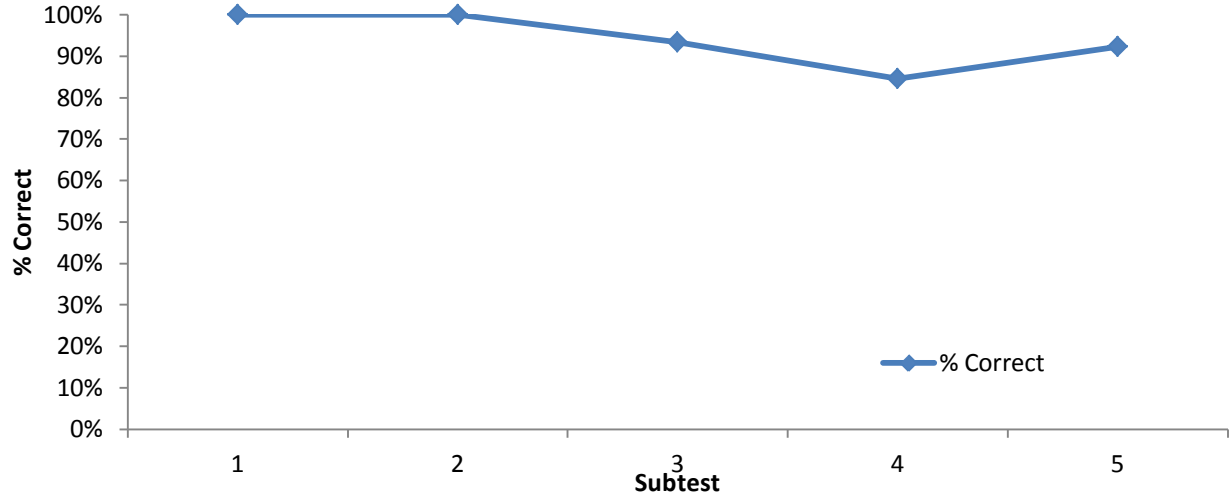
Figure 1.3. Participant 1's correctness trend for the TABE during the treatment phase.
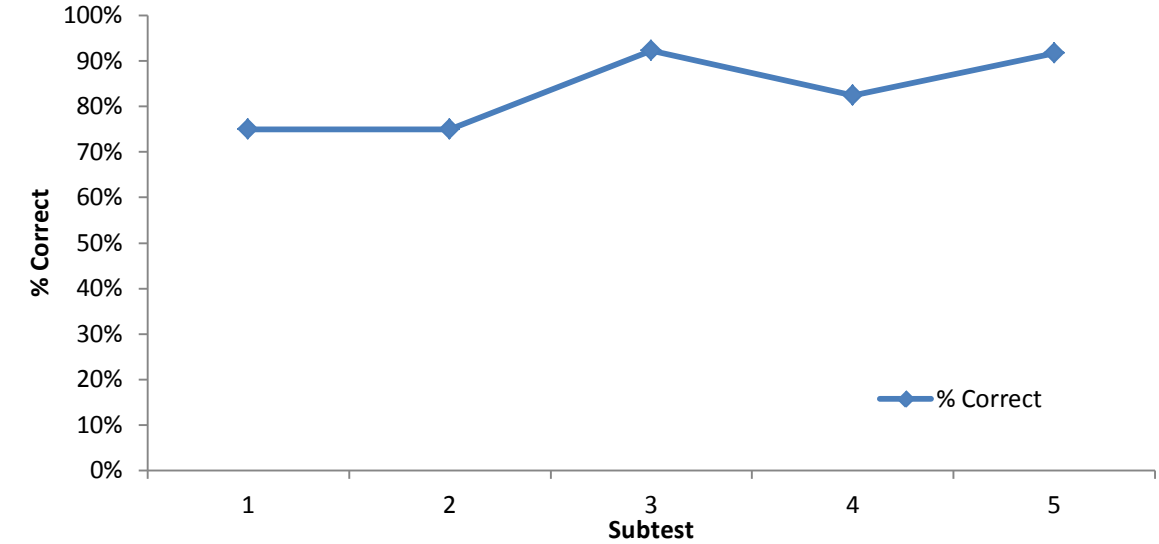
Figure 1.4. Participant 1's correctness trend for the TABE during the reversal phase.
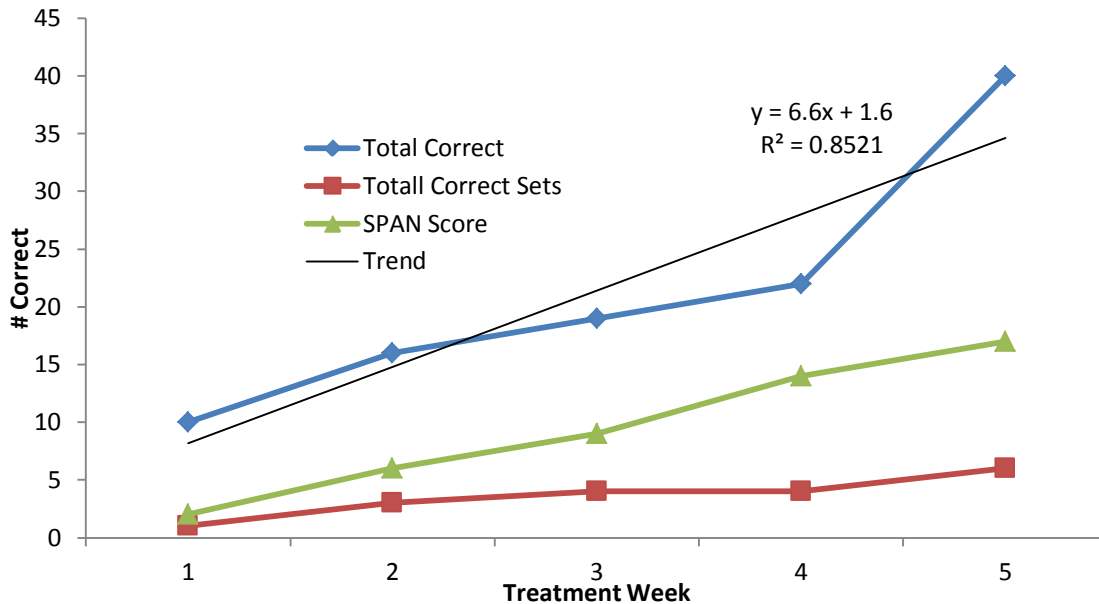
Figure 1.5. Participant 1's correctness data for the working memory treatment phase. (Increase indicates improved performance on working memory training tasks.)

For each graph representing working memory training scores the trend and variability are analyzed. The mean of the working memory training scores was not analyzed because the scores themselves are already means of weekly data. Figure 1.5 shows values of correctness and SPAN scores over the five weeks of the intervention phase. The data points of the treatment indicate a small variability, a large upward trend, and a trend line with a large effect ($R^2 = .85$). This trend line indicated that participant 1's working memory training scores were greatly improving over time.

Figure 1.6 shows values of error over the five weeks of the intervention phase. The data points of the intervention phase indicated a medium variability, a large downward trend, and a trend line with a large effect ($R^2 = .51$). This trend line indicated that participant 1's working memory training errors were greatly decreasing over time.
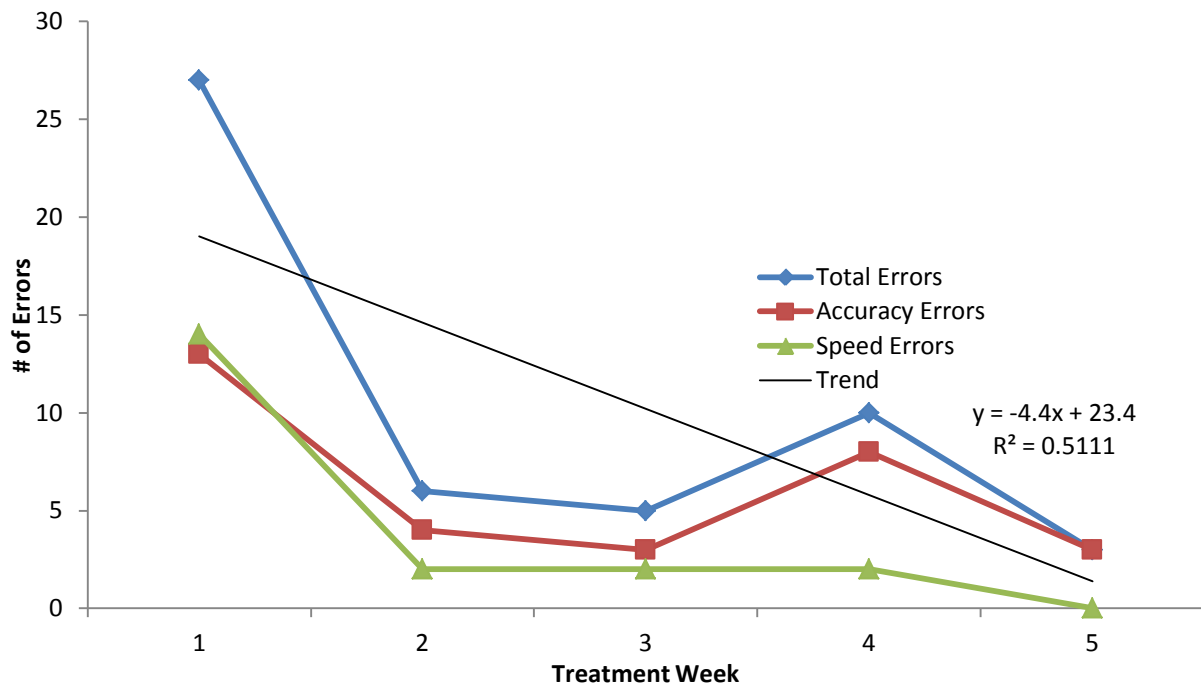
Figure 1.6. Participant 1's error data for the working memory treatment phase. (Decrease

indicates improved performance on working memory training tasks.)
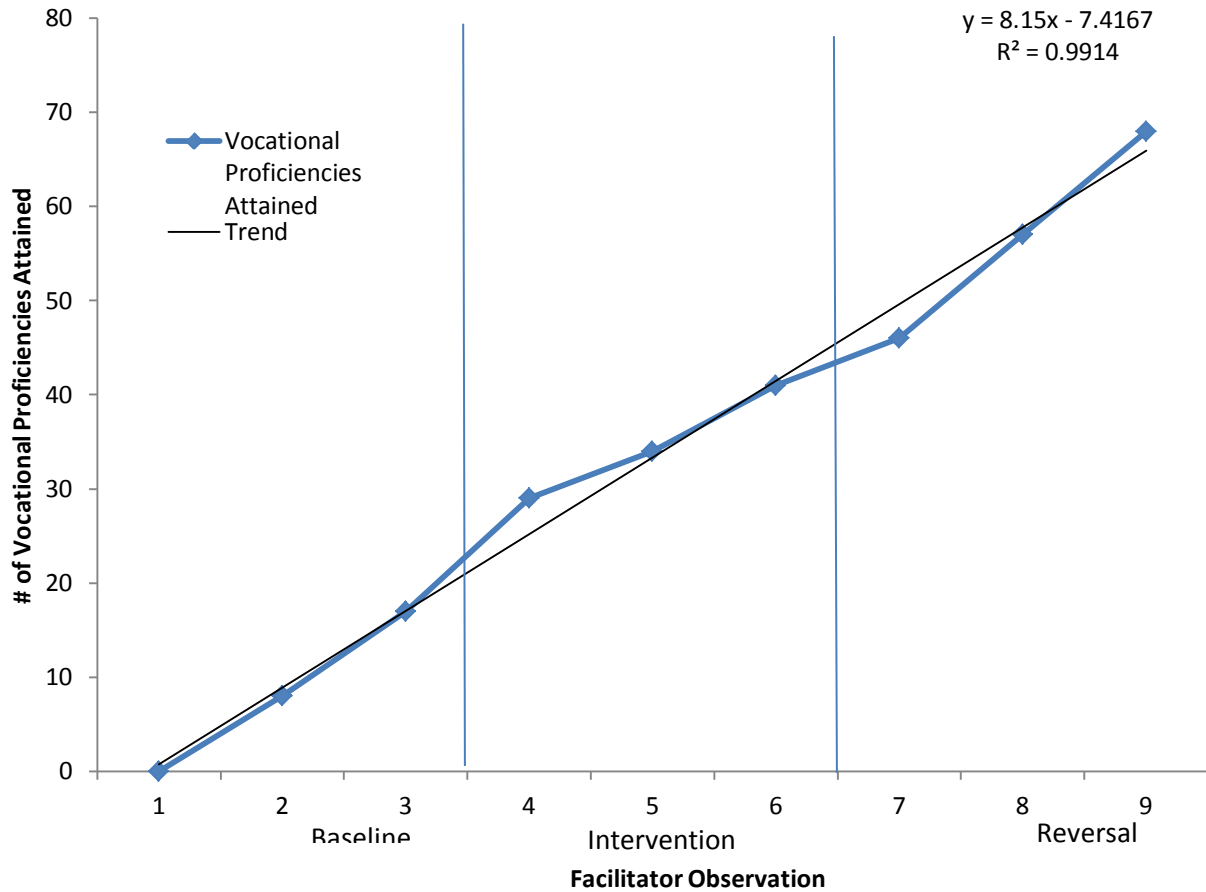
Figure 1.7. Participant 1's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TAR.)

Figure 1.7 represents the correct number of vocational proficiencies attained for each individual over the course of the baseline, treatment, and reversal phases. The number of vocational proficiencies attained should increase over time. Once a participant's evaluation indicates they have met a standard in vocational progress it will stay attained. Therefore visual analysis of levels between phases was conducted through examination of each phase's slope.

Visual analysis of trend was also conducted by examining the least squares regression. The trend data, shown in Figure 1.7, indicated an upward movement through visual analysis.

When calculating the least squares regression, a very strong relationship ($R^2 = 0.99$) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 1's TABE scores indicated a very small amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line.
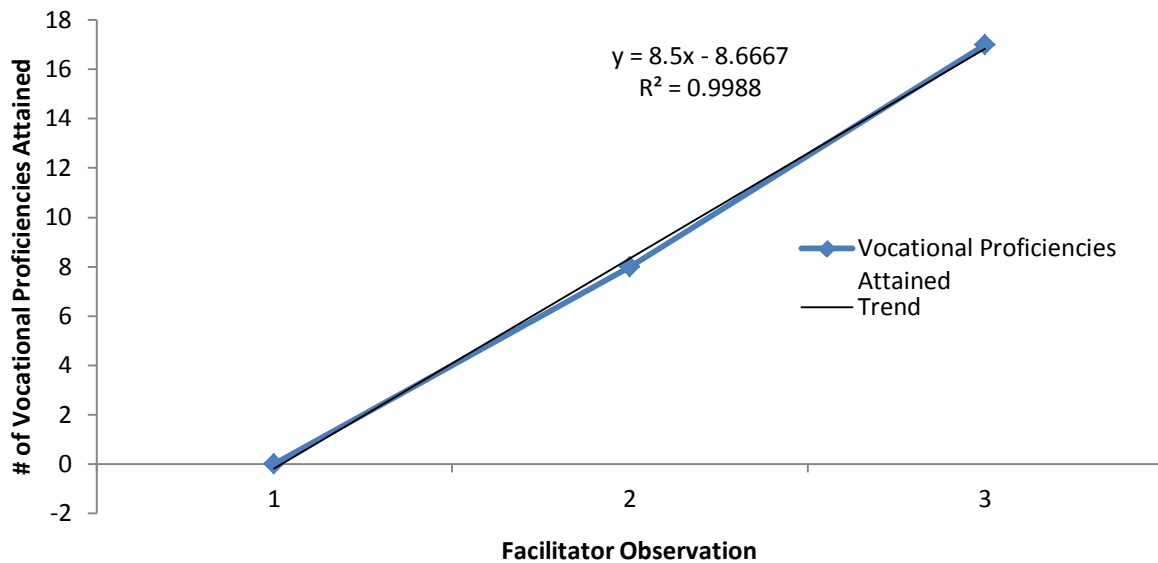
Figure 1.8. Participant 1's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline phase.

For each individual phase the level, trend, and variability is analyzed. Figure 1.8 shows TAR data for the baseline phase. The data points of the baseline phase indicate a small variability, an upward trend, a slope of 8.5, and a trend line with a large effect ($R^2 = .99$). This trend line indicated that participant 1's TAR scores were improving without intervention over time.

Figure 1.9 shows TAR data for the intervention phase. The data points of the intervention phase indicated a low variability, an upward trend, a slope of 6, and a trend line with a large effect (R^2 = .99). This trend line indicated that participant 1's TAR scores were still trending upward with intervention over time.

Figure 1.10 shows TAR data for the reversal phase. The data for the reversal phase indicated a low variability, an upward trend, a slope of 11, and a trend line with a large effect (R^2 = 1). This trend line indicated that participant 1's TAR scores were improving after the intervention over time.
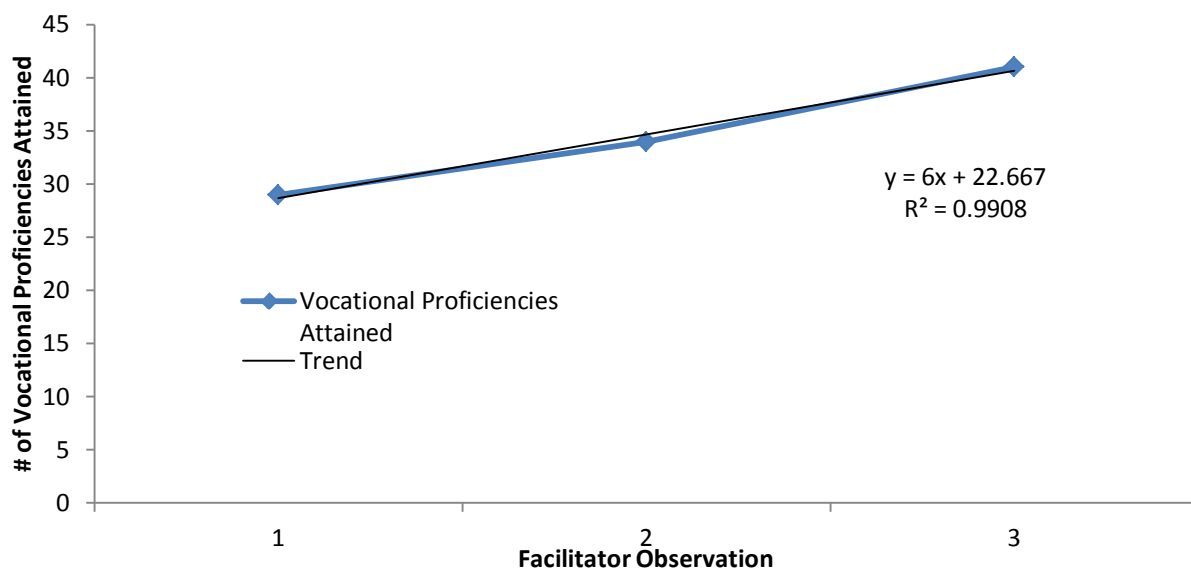
Figure 1.9. Participant 1's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the intervention phase.
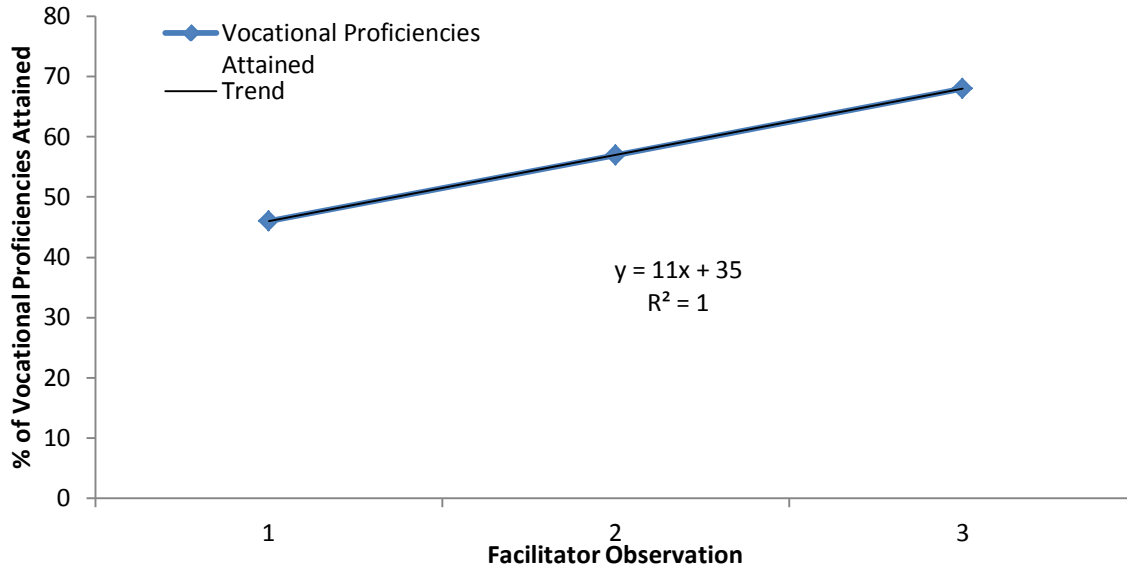
Figure 1.10. Participant 1's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the reversal phase.

Participant 2

Participant 2was evaluated using the TABE test of numerical reasoning and observed using TAR vocational progress monitoring survey. Participant 2 received five weeks of working memory training during the intervention phase.
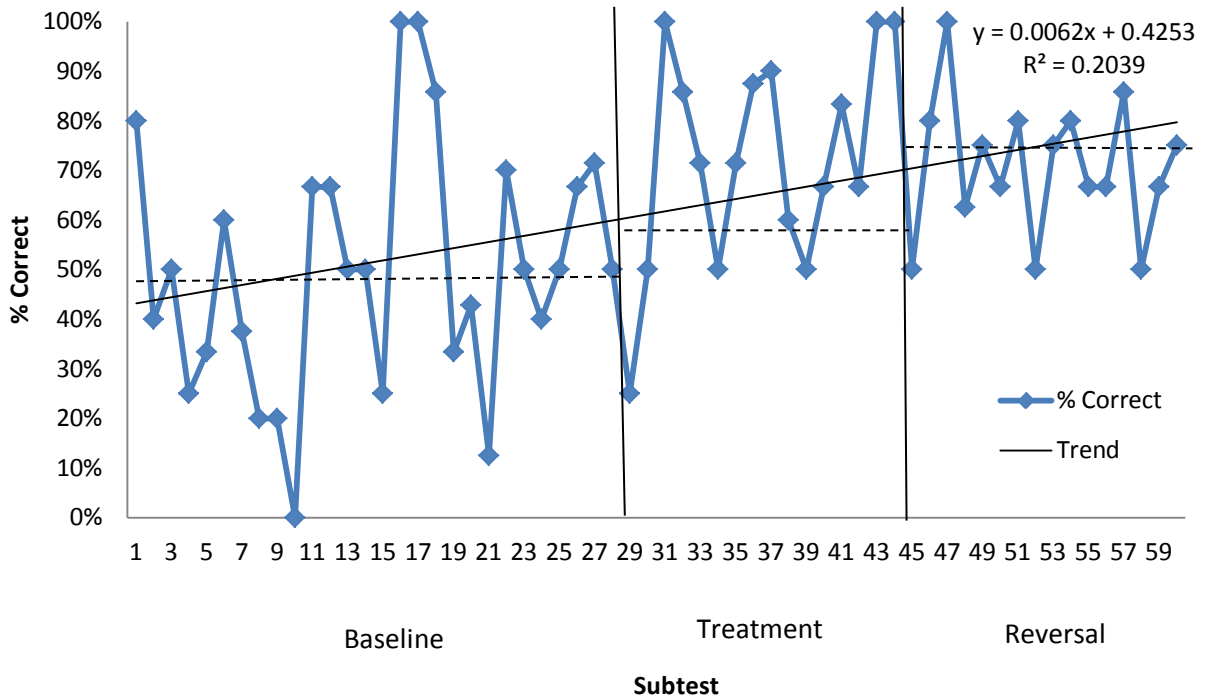
Figure 2.1. Participant 2's correctness on TABE tests of numerical reasoning during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

Figure 2.1 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 2.1 provides a graphical representation of the observed TABE scores for participant 2 across all phases of the study. The visual analysis of levels between phases was conducted through examination of each phase's mean. As is evident from the graph, the mean of each phase (shown by the dashed black line) increased over the study. In Phase 1, the mean was 49%; in Phase 2, the mean was 57%, and in Phase 3, the mean was 72%. The increase in mean over time showed that participant 2's percentage of correctness on the TABE exam increased.

Visual analysis of trend was also conducted by examining the least squares regression. The trend is the slope and magnitude of the data that is described qualitatively. The trend data, shown in Figure 2.1, indicated an upward movement through visual analysis. When calculating

the least squares regression, a medium relationship ($R^2 = .20$) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 2's TABE scores indicated a large amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation was calculated to show the dispersion from the average. Participant 2's standard deviation for the entire experiment was 23.9% ($\sigma = .239$, $\sigma^2 = .057$).
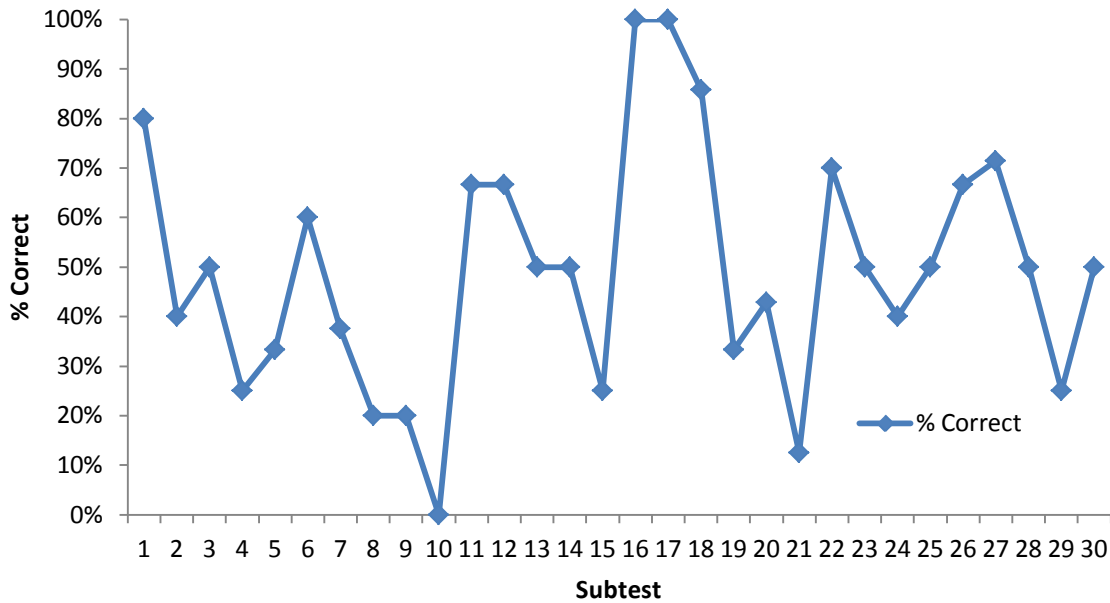
Figure 2.2. Participant 2's correctness trend for the TABE during the baseline phase.

For each individual phase the level and variability was analyzed. Figure 2.2 shows TABE data for the baseline phase. The data points of the baseline phase indicate a mean of 49% and a standard deviation of 24.5% ($\sigma = .245$, $\sigma^2 = .057$). Figure 2.3 shows TABE data for the intervention phase. The data points of the intervention phase indicated a mean of 57% and a

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standard deviation of 18.3% ($\sigma = .183,\ \sigma^2 = .034$). Figure 2.4 shows TABE data for the reversal phase. The data for the reversal phase indicated a mean of 72% and a standard deviation of 12.9% ($\sigma = .129,\ \sigma^2 = .016$).
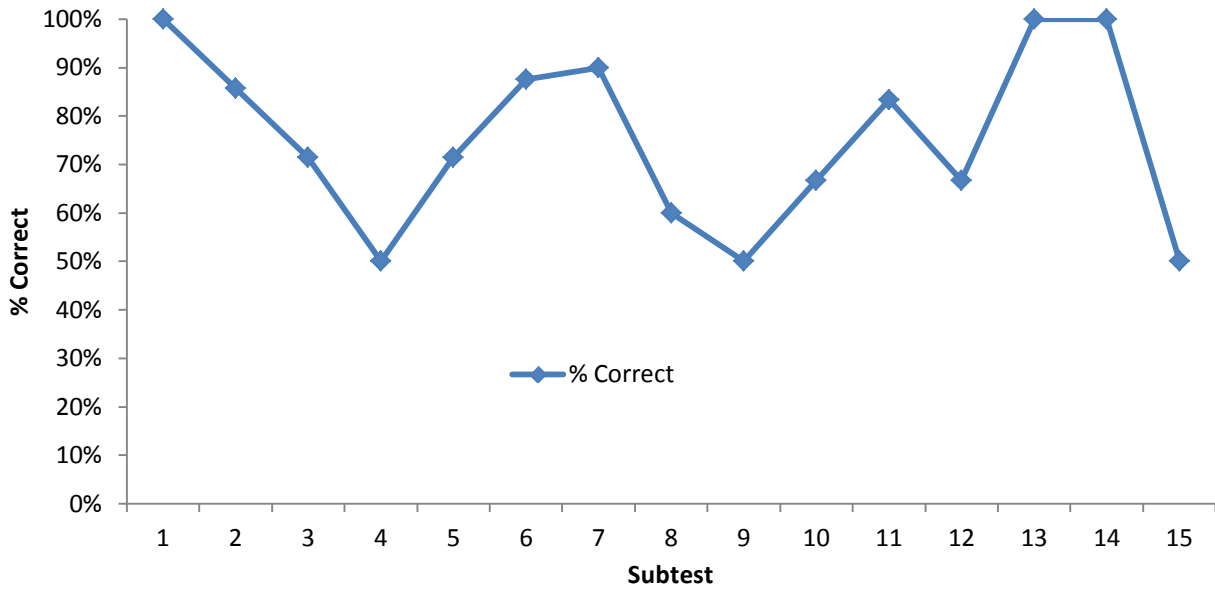
Figure 2.3. Participant 2's correctness trend for the TABE during the treatment phase.
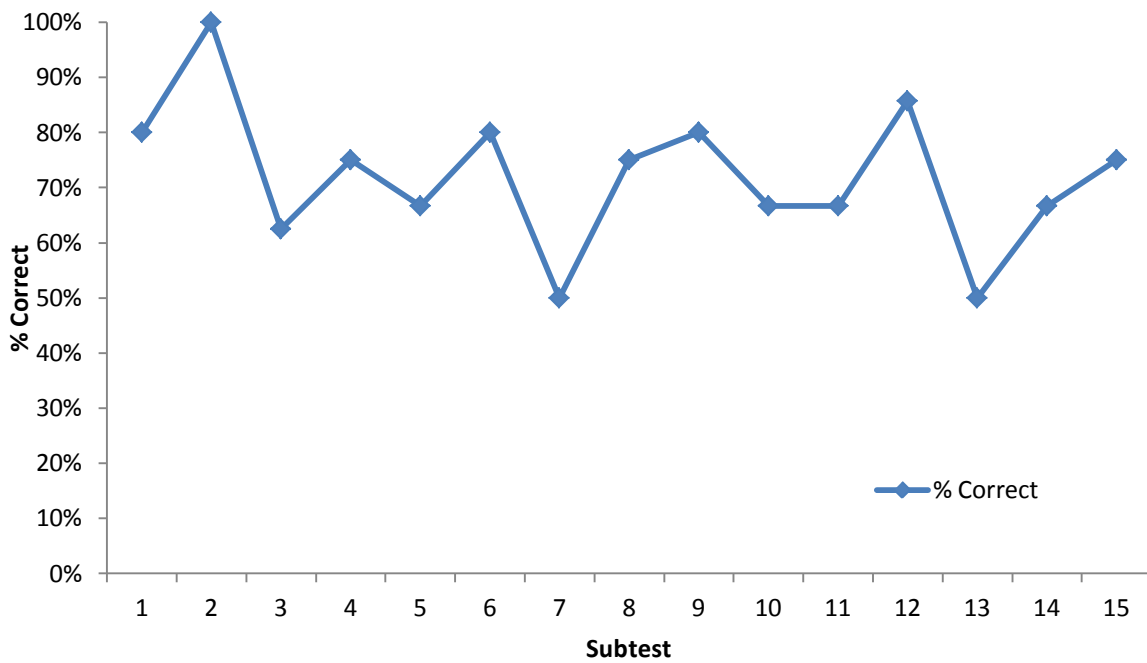
Figure 2.4. Participant 2's correctness trend for the TABE during the reversal phase.
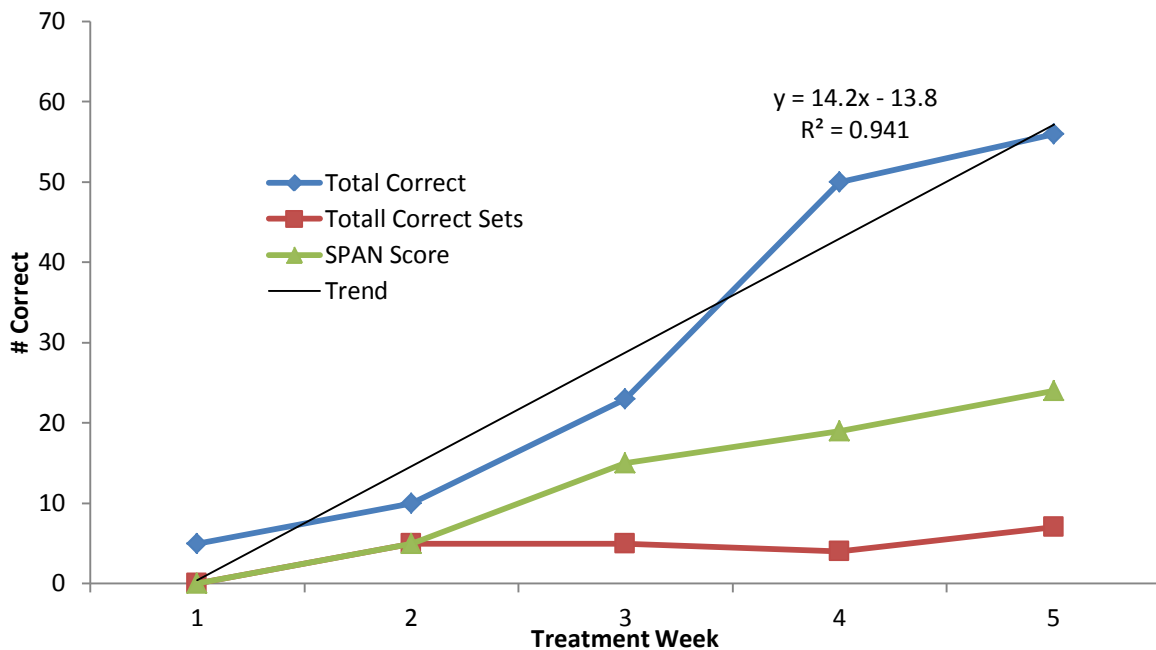
Figure 2.5. Participant 2's correctness data for the working memory treatment phase. (Increase indicates improved performance on working memory training tasks.)

For each graph representing working memory training scores the trend and variability are analyzed. Figure 2.5 shows values of correctness and SPAN scores over the five weeks of the intervention phase. The data points of the treatment indicate a small variability, a large upward trend, and a trend line with a large effect ($R^2 = .94$). This trend line indicated that participant 2's working memory training scores were greatly improving over time.

Figure 2.6 shows values of error over the five weeks of the intervention phase. The data points of the intervention phase indicated a medium variability, a large downward trend, and a trend line with a large effect ($R^2 = .78$). This trend line indicated that participant 2's working memory training errors were greatly decreasing over time.

$$y = -9.2x + 43.8$$
$$R^2 = 0.7875$$
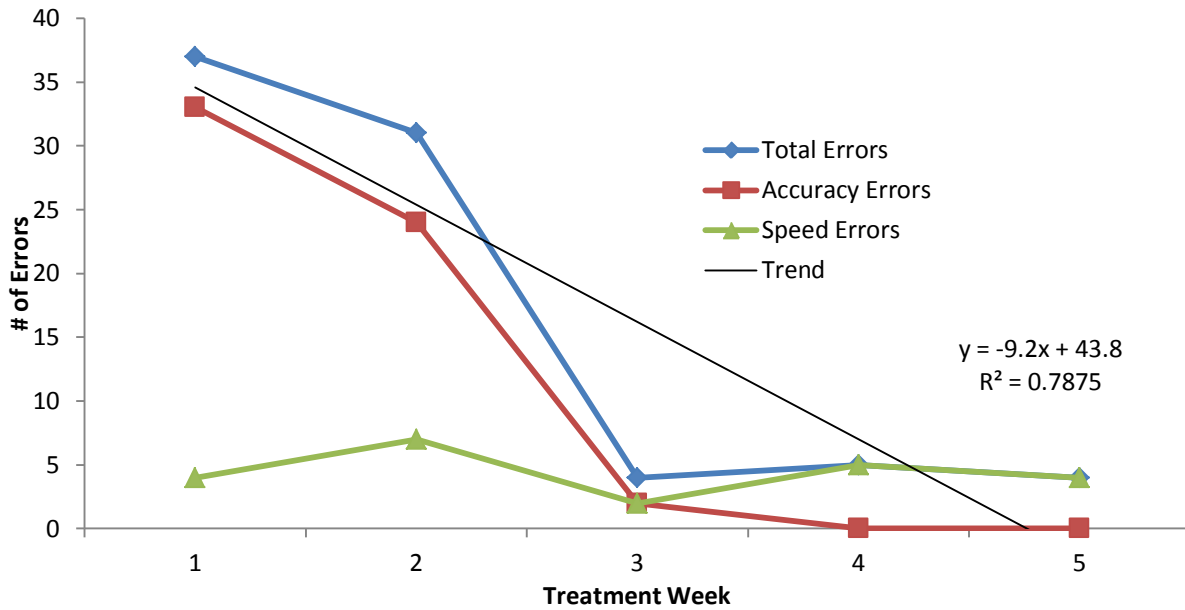
Figure 2.6. Participant 2's error data for the working memory treatment phase. (Decrease indicates improved performance on working memory training tasks.)
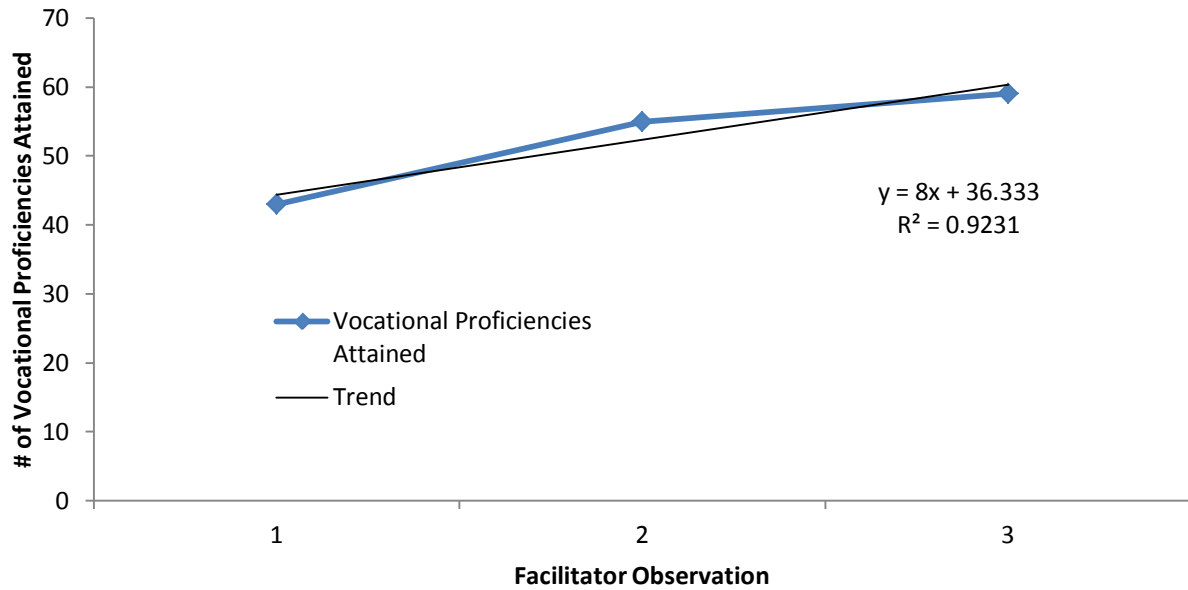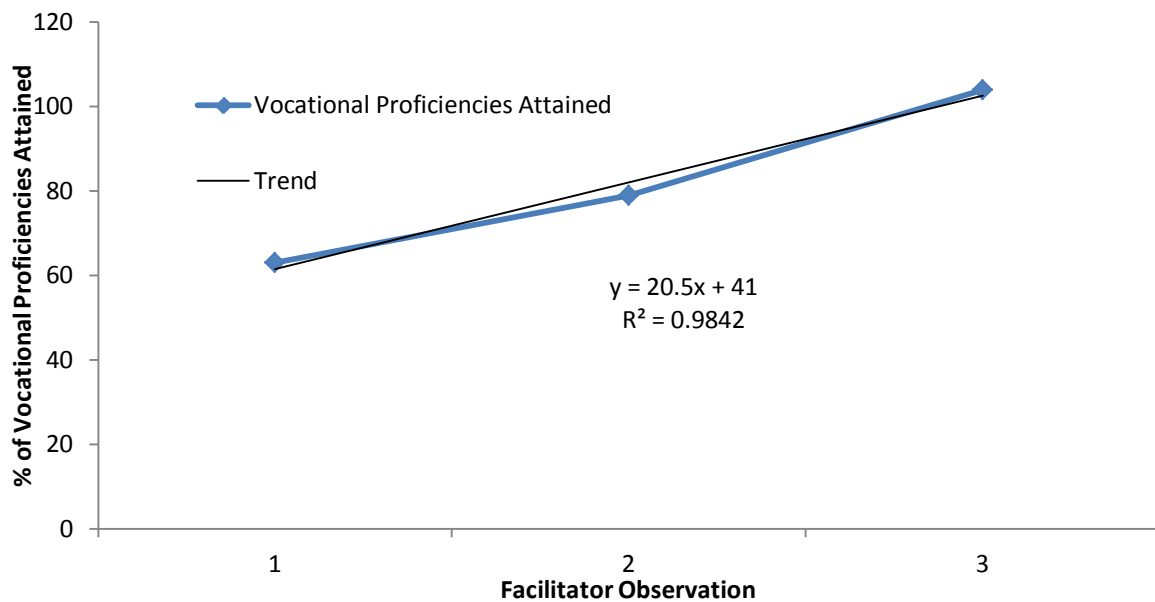

$$y = 8.5333x + 13.222$$
$$R^2 = 0.9204$$
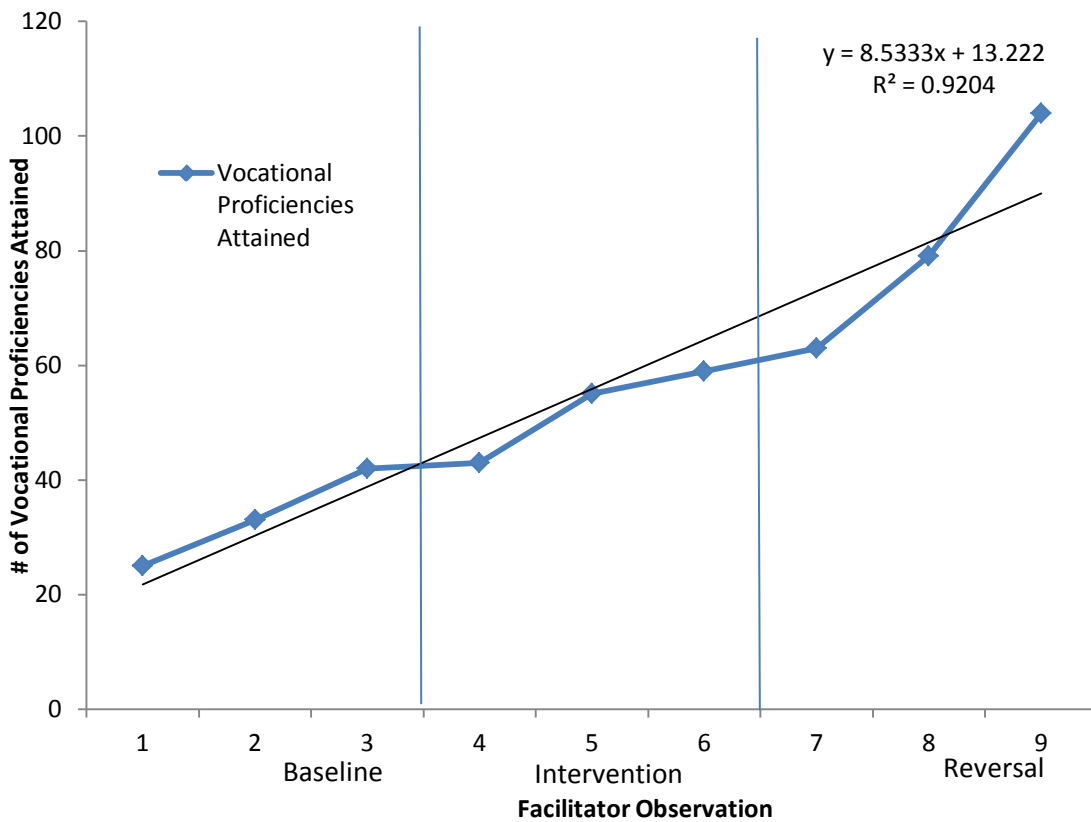
Figure 2.7. Participant 2's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TAR.)

Figure 2.7 represents the correct number of vocational proficiencies attained for each individual over the course of the baseline, treatment, and reversal phases. The number of vocational proficiencies attained should increase over time. Once a participant's evaluation indicates they have met a standard in vocational progress it will stay attained. Therefore visual analysis of levels between phases was conducted through examination of each phase's slope and mean.

Visual analysis of trend was also conducted by examining the least squares regression. The trend data, shown in Figure 2.7, indicated an upward movement through visual analysis. When calculating the least squares regression, a very strong relationship ($R^2 = 0.92$) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 2's TABE scores indicated a very small amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line.
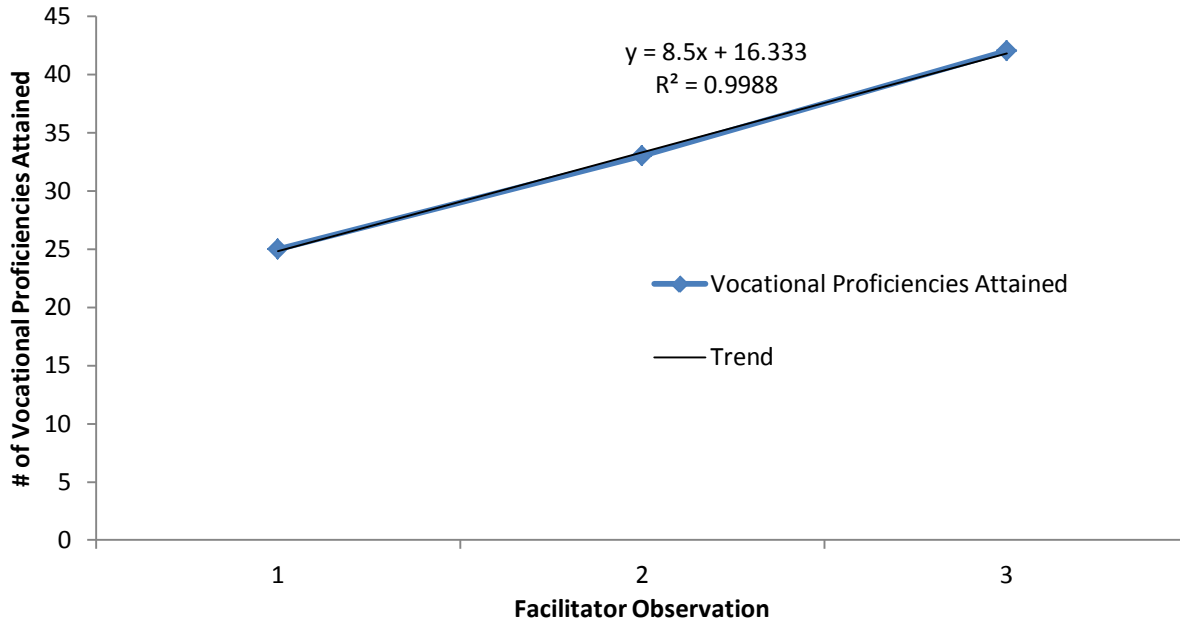
Figure 2.8. Participant 2's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline phase.

For each individual phase the level, trend, and variability is analyzed. Figure 2.8 shows TAR data for the baseline phase. The data points of the baseline phase indicate a small variability, an upward trend, a slope of 8.5, and a trend line with a large effect ($R^2 = .99$). This trend line indicated that participant 2's TAR scores were improving without intervention over time.

Figure 2.9 shows TAR data for the intervention phase. The data points of the intervention phase indicated a low variability, an upward trend, a slope of 8, and a trend line with a large effect ($R^2 = .92$). This trend line indicated that participant 2's TAR scores were still trending upward with intervention over time.

Figure 2.10 shows TAR data for the reversal phase. The data for the reversal phase indicated a low variability, an upward trend, a slope of 20.5, and a trend line with a large effect

$(R^2 = .98)$. This trend line indicated that participant 2's TAR scores were improving after the intervention over time.

Figure 2.9. Participant 2's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the intervention phase.

Figure 2.10. Participant 2's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the reversal phase.

Participant 3

Participant 3was evaluated using the TABE test of reading comprehension and observed using TAR vocational progress monitoring survey. Participant 3 received five weeks of working memory training during the intervention phase.
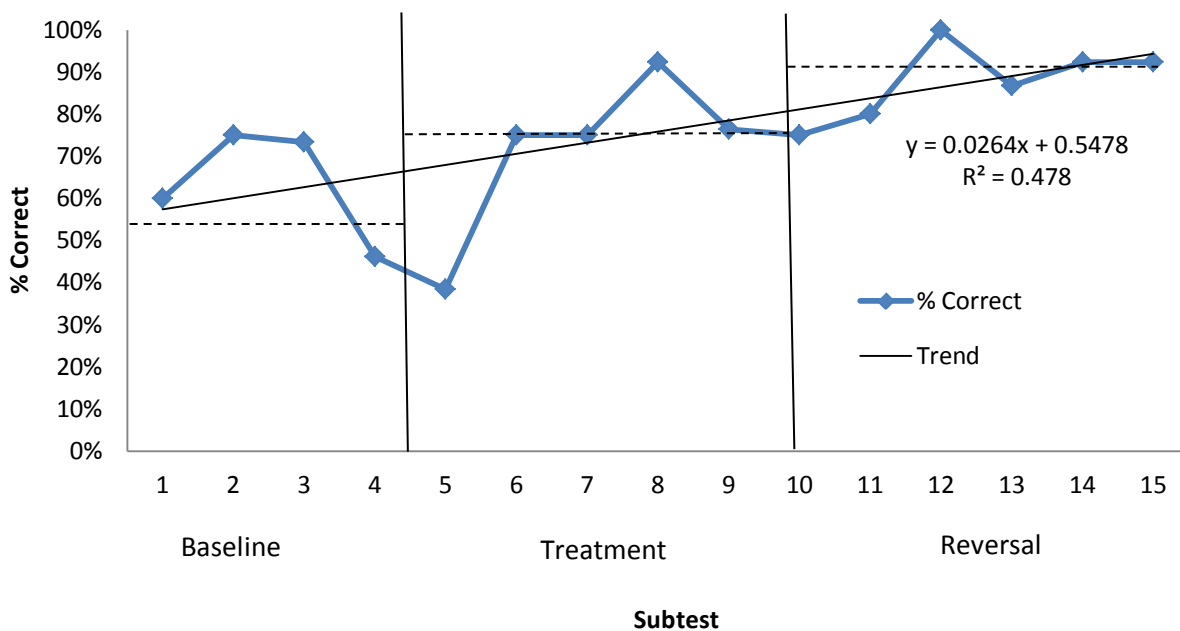
Figure 3.1. Participant 3's correctness on TABE tests of reading comprehension during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

Figure 3.1 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 3.1 provides a graphical representation of the observed TABE scores for participant 3 across all phases of the study. The

visual analysis of levels between phases was conducted through examination of each phase's mean. As is evident from the graph, the mean of each phase (shown by the dashed black line) increased over the study. In Phase 1, the mean was 59%; in Phase 2, the mean was 79%, and in Phase 2, the mean was 90%. The increase in mean over time showed that participant 3's percentage of correctness on the TABE exam increased.

Visual analysis of trend was also conducted by examining the least squares regression. The trend is the slope and magnitude of the data that is described qualitatively. The trend data, shown in Figure 3.1, indicated an upward movement through visual analysis. When calculating the least squares regression, a large relationship ($R^2 = .48$) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 3's TABE scores indicated a moderate amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation was calculated to show the dispersion from the average. Participant 3's standard deviation for the entire experiment was 17.1% ($\sigma = .171$, $\sigma^2 = .029$).

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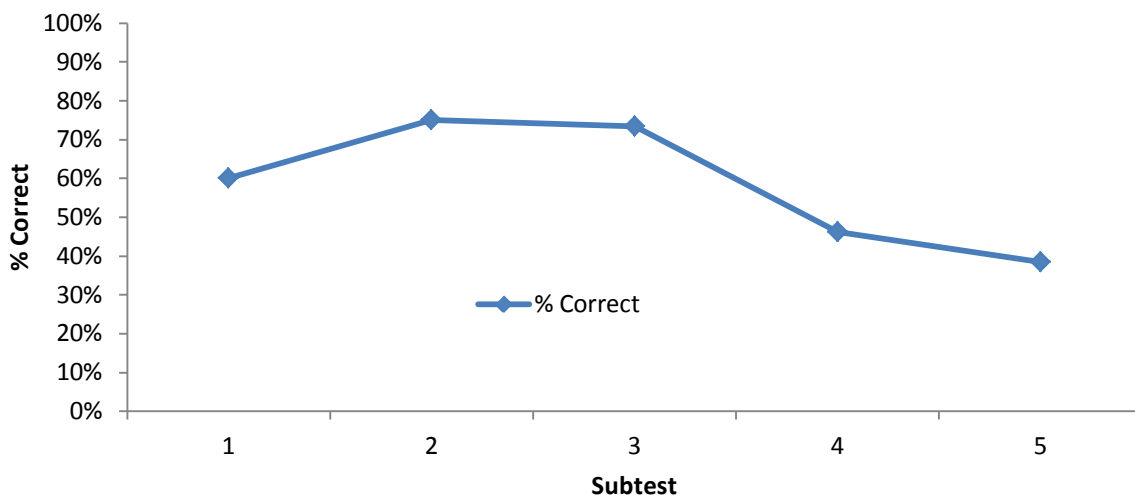
Figure 3.2. Participant 3's correctness trend for the TABE during the baseline phase.

For each individual phase the level and variability was analyzed. Figure 3.2 shows TABE data for the baseline phase. The data points of the baseline phase indicate a a mean of 59% and a standard deviation of 16.2% ($\sigma = .162$, $\sigma^2 = .026$). Figure 3.3 shows TABE data for the intervention phase. The data points of the intervention phase indicated a mean of 79% and a standard deviation of 7.6% ($\sigma = .076$, $\sigma^2 = .006$). Figure 3.4 shows TABE data for the reversal phase. The data for the reversal phase indicated a mean of 90% and a standard deviation of 7.4% ($\sigma = .074$, $\sigma^2 = .005$). This trend line indicated that participant 3's TABE scores were improved from the baseline and intervention phases.
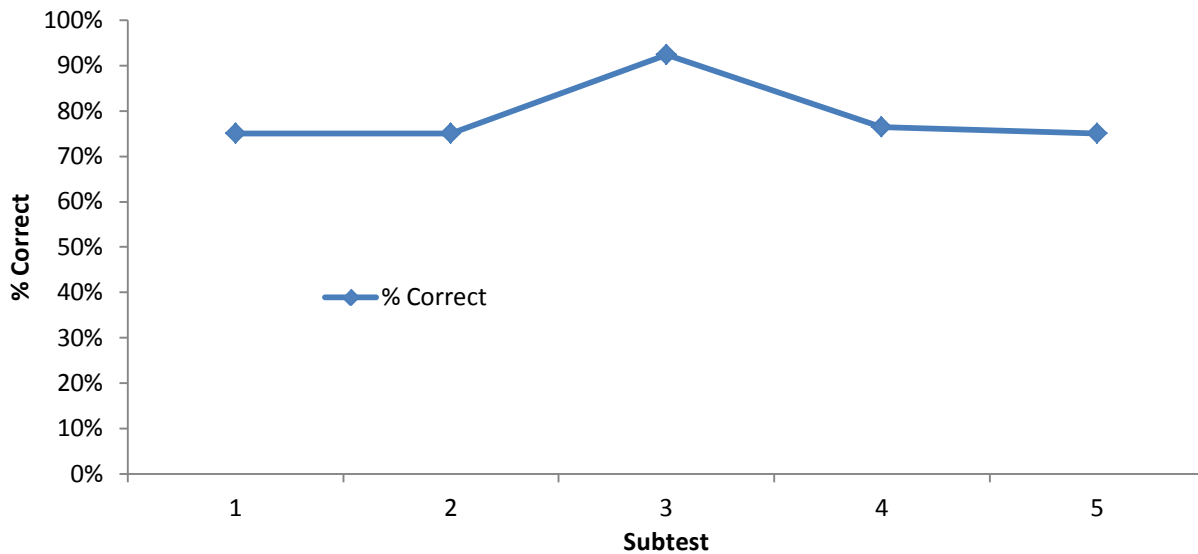
Figure 3.3. Participant 3's correctness trend for the TABE during the treatment phase.
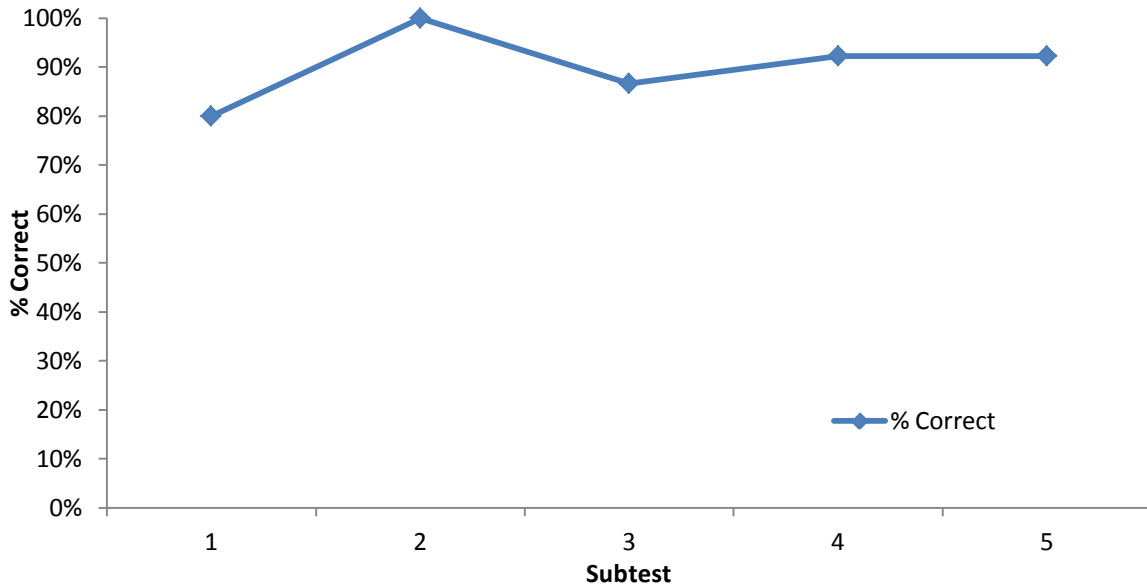
Figure 3.4. Participant 3's correctness trend for the TABE during the reversal phase.

$$y = -0.7x + 51.9$$
$$R^2 = 0.0057$$
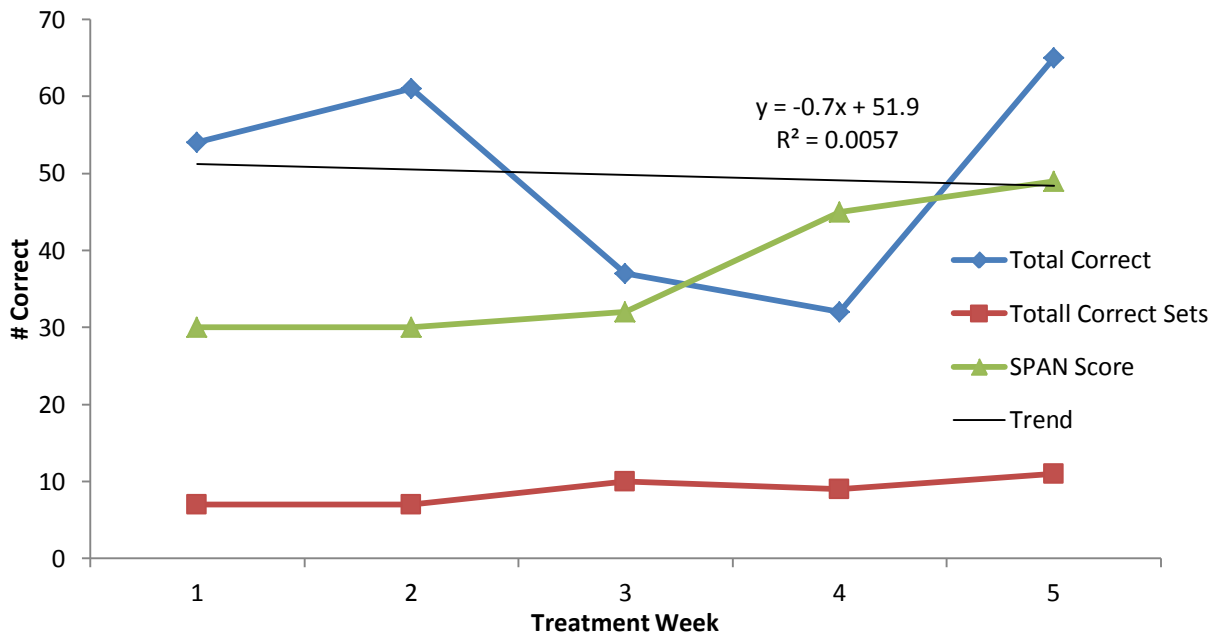
Figure 3.5. Participant 3's correctness data for the working memory treatment phase. (Increase indicates improved performance on working memory training tasks.)

For each graph representing working memory training scores the trend and variability are analyzed. Figure 3.5 shows values of correctness and SPAN scores over the five weeks of the intervention phase. The data points of the treatment indicate a small variability, a large upward

trend, and a trend line with a small effect ($R^2 = .005$). This trend line indicated that participant 3's working memory training scores were relatively consistent over time.

Figure 3.6 shows values of error over the five weeks of the intervention phase. The data points of the intervention phase indicated a medium variability, a large downward trend, and a trend line with a large effect ($R^2 = .30$). This trend line indicated that participant 3's working memory training errors were greatly decreasing over time.
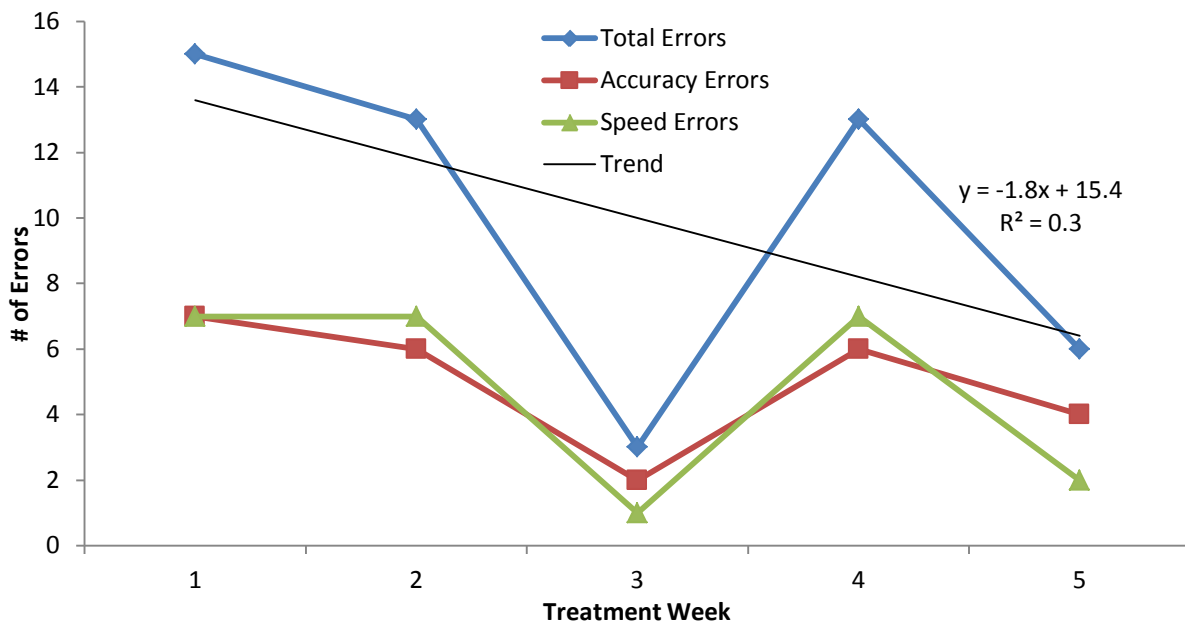
Figure 3.6. Participant 3's error data for the working memory treatment phase. (Decrease indicates improved performance on working memory training tasks.)
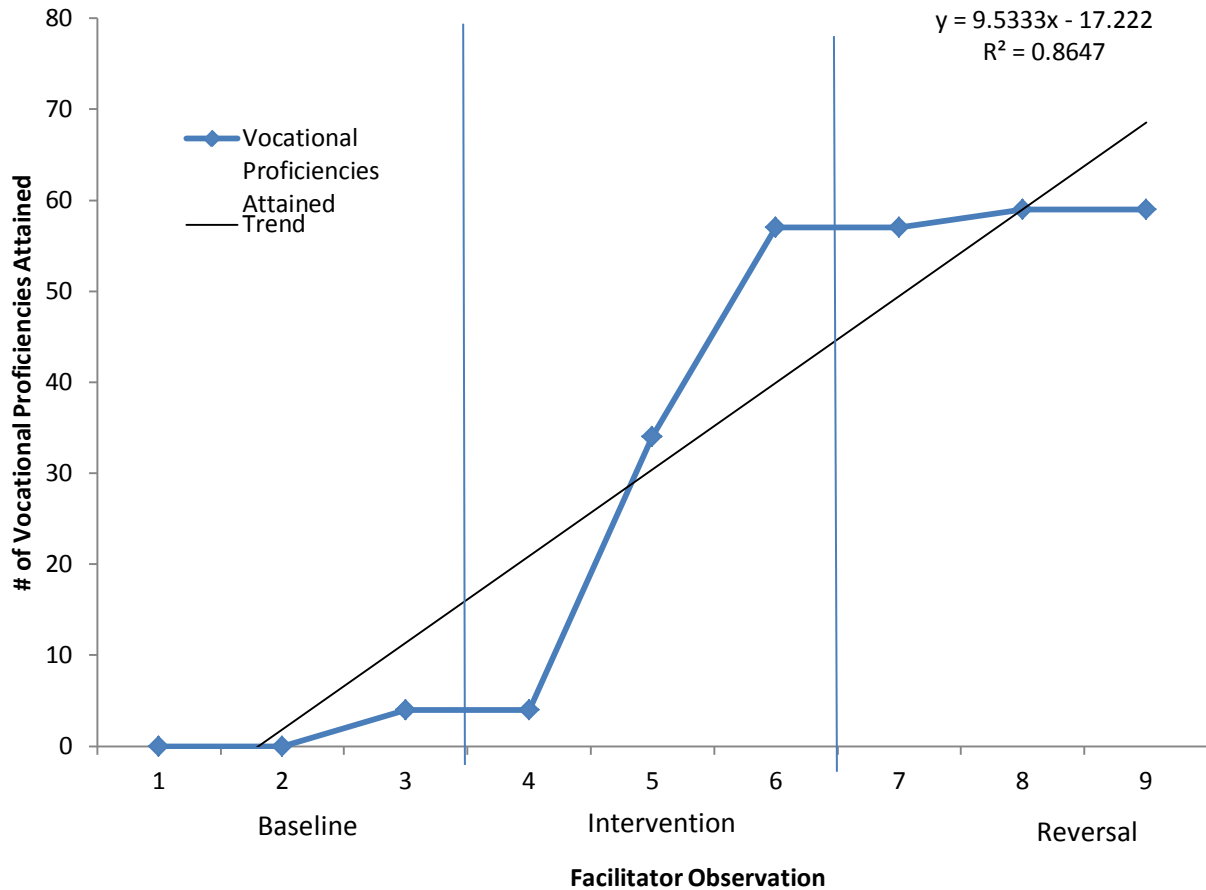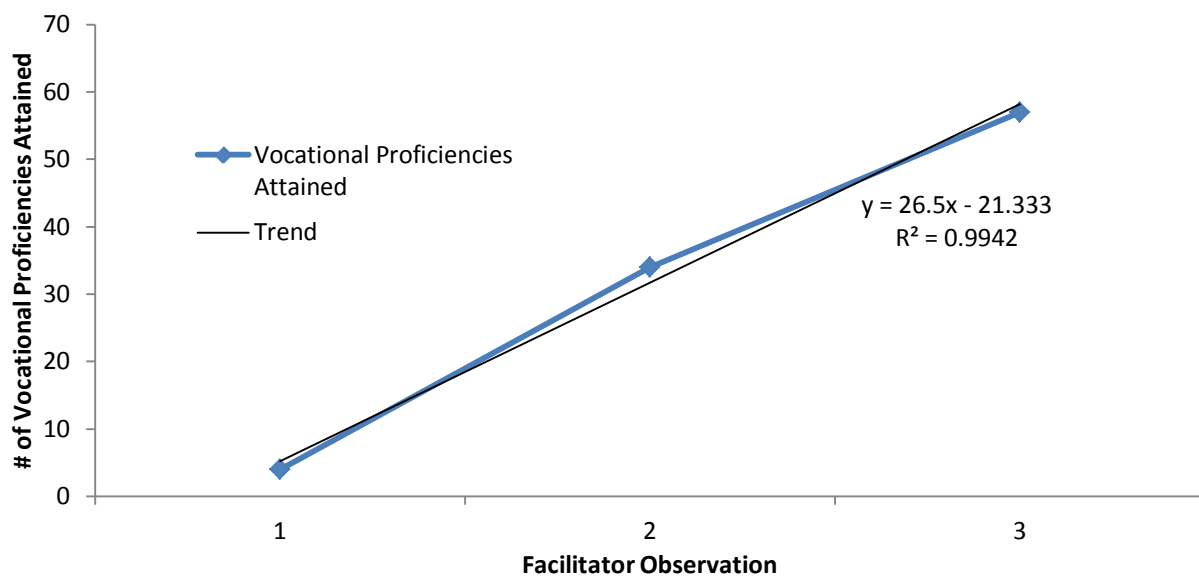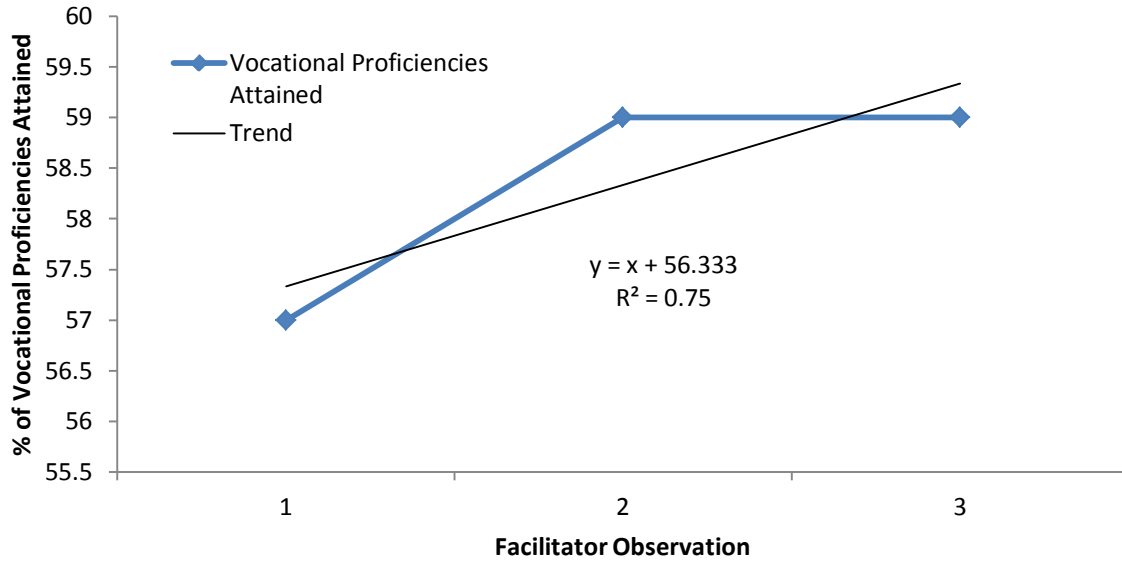
Figure 3.7. Participant 3's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TAR.)

Figure 3.7 represents the correct number of vocational proficiencies attained for each individual over the course of the baseline, treatment, and reversal phases. The number of vocational proficiencies attained should increase over time. Once a participant's evaluation indicates they have met a standard in vocational progress it will stay attained. Therefore visual analysis of levels between phases was conducted through examination of each phase's slope and mean.

Visual analysis of trend was also conducted by examining the least squares regression. The trend data, shown in Figure 3.7, indicated an upward movement through visual analysis.

When calculating the least squares regression, a very strong relationship ($R^2 = .86$) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 3's TABE scores indicated a very small amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line.

The plot shows "# of Vocational Proficiencies Attained" on the y-axis (0 to 4.5) versus "Facilitator Observation" (1 to 3) on the x-axis. Legend: Vocational Proficiencies Attained; Trend. Equation: $y = 2x - 2.6667$, $R^2 = 0.75$.
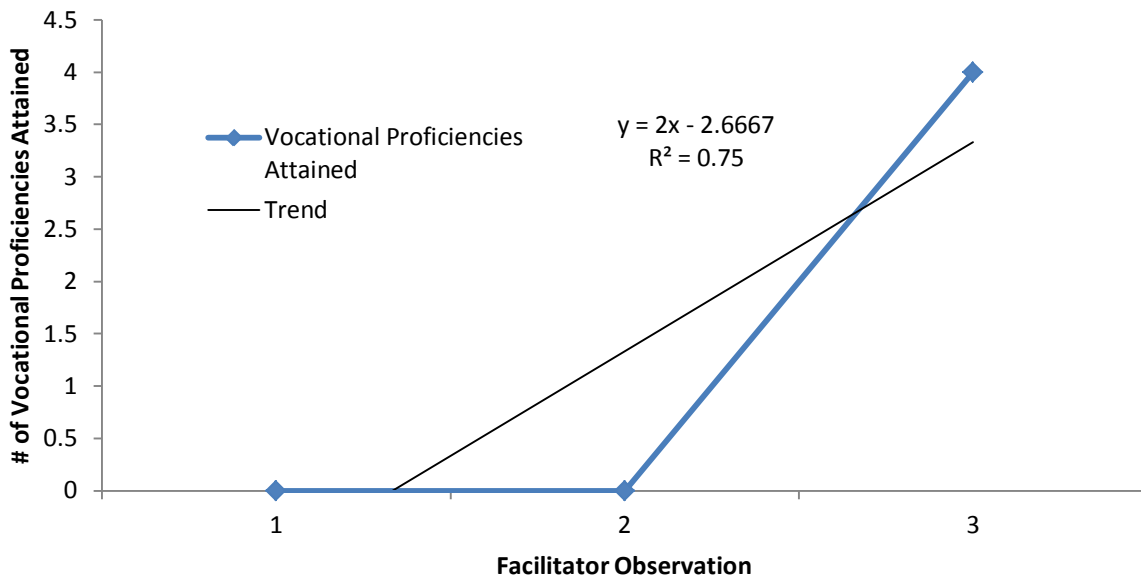
Figure 3.8. Participant 3's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline phase.

For each individual phase the level, trend, and variability is analyzed. Figure 3.8 shows TAR data for the baseline phase. The data points of the baseline phase indicate a small variability, an upward trend, a slope of 2, and a trend line with a large effect ($R^2 = .75$). This trend line indicated that participant 3's TAR scores were improving without intervention over time.

Figure 3.9 shows TAR data for the intervention phase. The data points of the intervention phase indicated a low variability, an upward trend, a slope of 26.5, and a trend line with a large effect (R^2 = .99). This trend line indicated that participant 3's TAR scores were still trending upward with intervention over time.

Figure 3.10 shows TAR data for the reversal phase. The data for the reversal phase indicated a low variability, an upward trend, a slope of 1, and a trend line with a large effect (R^2 = .75). This trend line indicated that participant 3's TAR scores were improving after the intervention over time.

Figure 3.9. Participant 3's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the intervention phase.

Figure 3.10. Participant 3's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the reversal phase.

Participant 4

Participant 4was evaluated using the TABE test of numerical reasoning and observed using TAR vocational progress monitoring survey. Participant 4 received five weeks of working memory training during the intervention phase.

The chart shows % Correct on the y-axis (0% to 100%) and Subtest on the x-axis (1 to 88), divided into three phases: Baseline, Treatment, and Reversal. The trend line equation is:

$$y = 0.0035x + 0.5039$$
$$R^2 = 0.2064$$
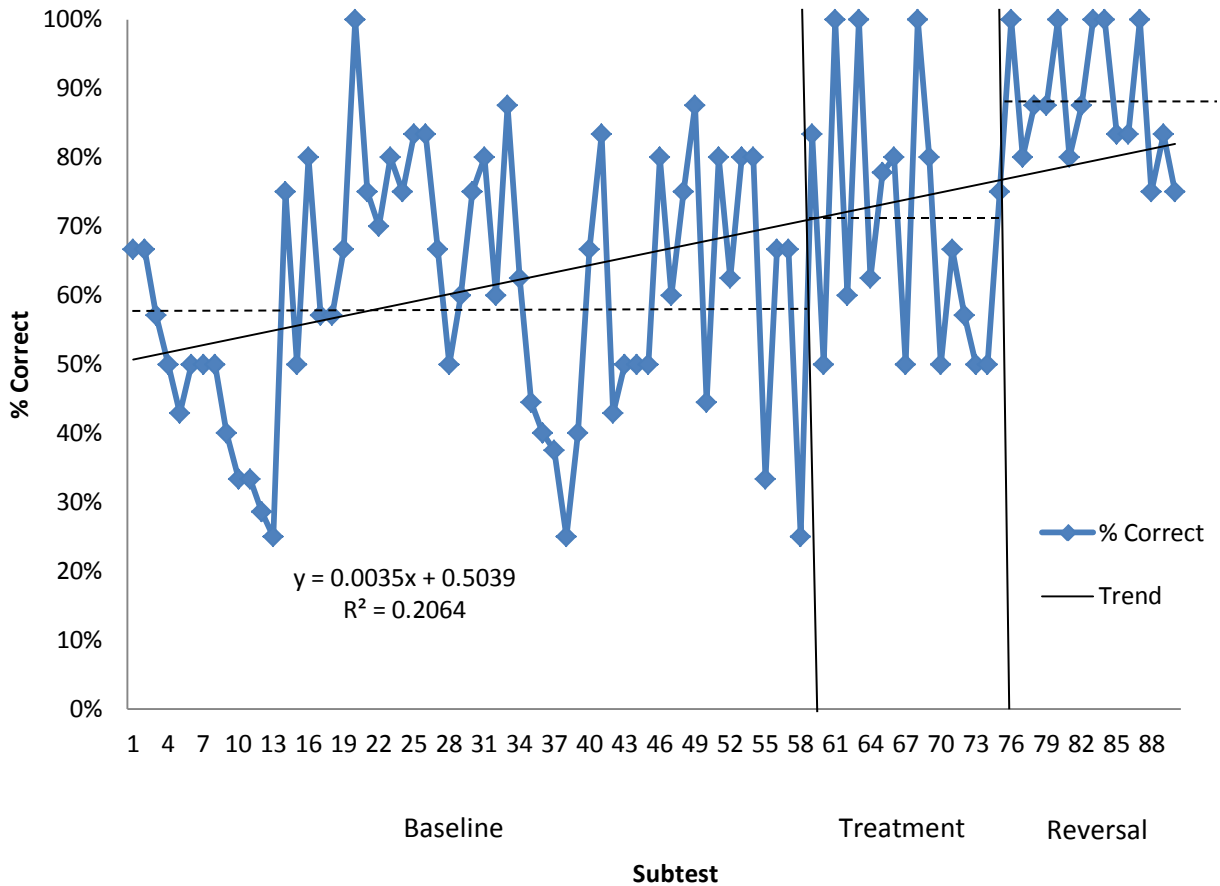
Figure 4.1. Participant 4's correctness on TABE tests of mathematics during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

    Figure 4.1 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 4.1 provides a graphical representation of the observed TABE scores for participant 4 across all phases of the study. The visual analysis of levels between phases was conducted through examination of each phase's mean. As is evident from the graph, the mean of each phase (shown by the dashed black line) increased over the study. In Phase 1, the mean was 60%; in Phase 2, the mean was 71%, and in Phase 3, the mean was 88%. The increase in mean over time showed that participant 4's percentage of correctness on the TABE exam increased.

Visual analysis of trend was also conducted by examining the least squares regression. The trend is the slope and magnitude of the data that is described qualitatively. The trend data, shown in Figure 4.1, indicated an upward movement through visual analysis. When calculating the least squares regression, a medium relationship ($R^2 = 0.21$) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 4's TABE scores indicated a large amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation was calculated to show the dispersion from the average. Participant 4's standard deviation for the entire experiment was 22.9% ($\sigma = .229$, $\sigma^2 = .052$).

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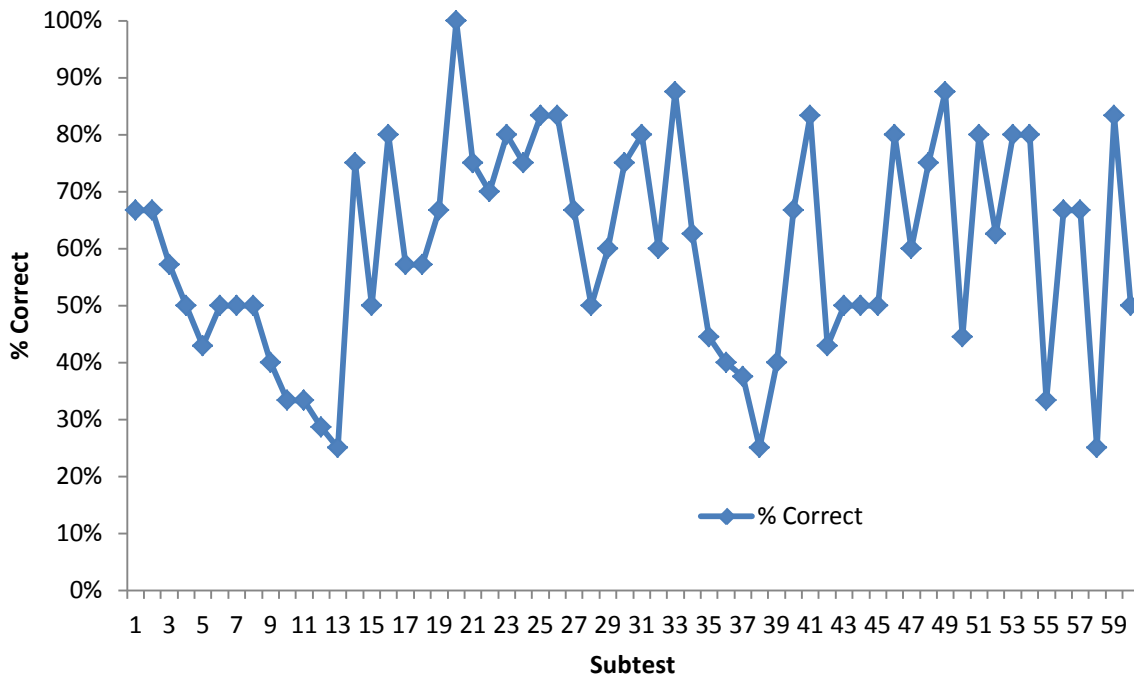
Figure 4.2. Participant 4's correctness trend for the TABE during the baseline phase.

For each individual phase the level and variability was analyzed. Figure 4.2 shows TABE data for the baseline phase. The data points of the baseline phase indicate a mean of 60% and a standard deviation of 18.5% ($\sigma = .185$, $\sigma^2 = .034$). Figure 4.3 shows TABE data for the intervention phase. The data points of the intervention phase indicated a 71% and a standard deviation of 28.4% ($\sigma = .284$, $\sigma^2 = .080$). Figure 4.4 shows TABE data for the reversal phase. The data for the reversal phase indicated a mean of 88% and a standard deviation of 21.4% ($\sigma = .214$, $\sigma^2 = .046$).
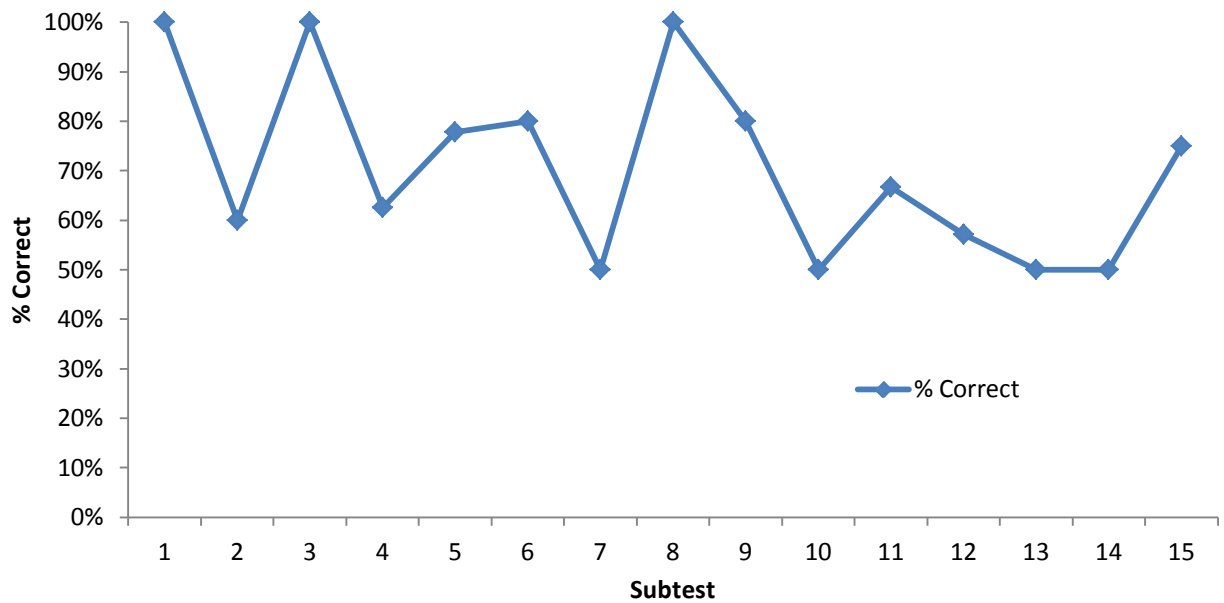
Figure 4.3. Participant 4's correctness trend for the TABE during the treatment phase.
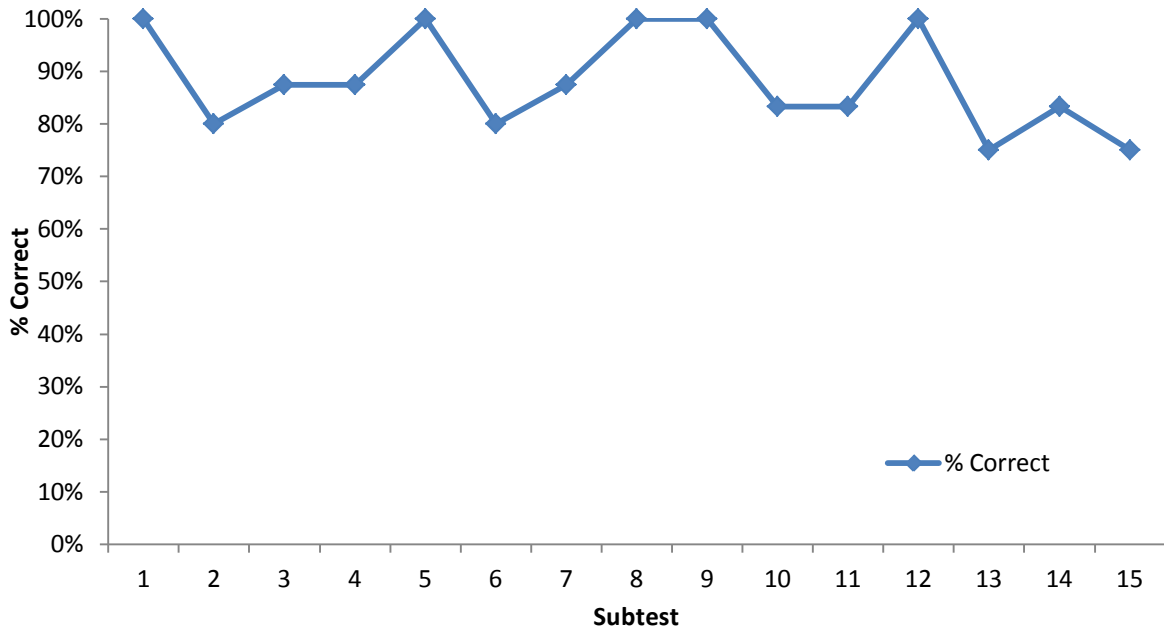
Figure 4.4. Participant 4's correctness trend for the TABE during the reversal phase.

$$y = 6.4x$$
$$R^2 = 0.8627$$
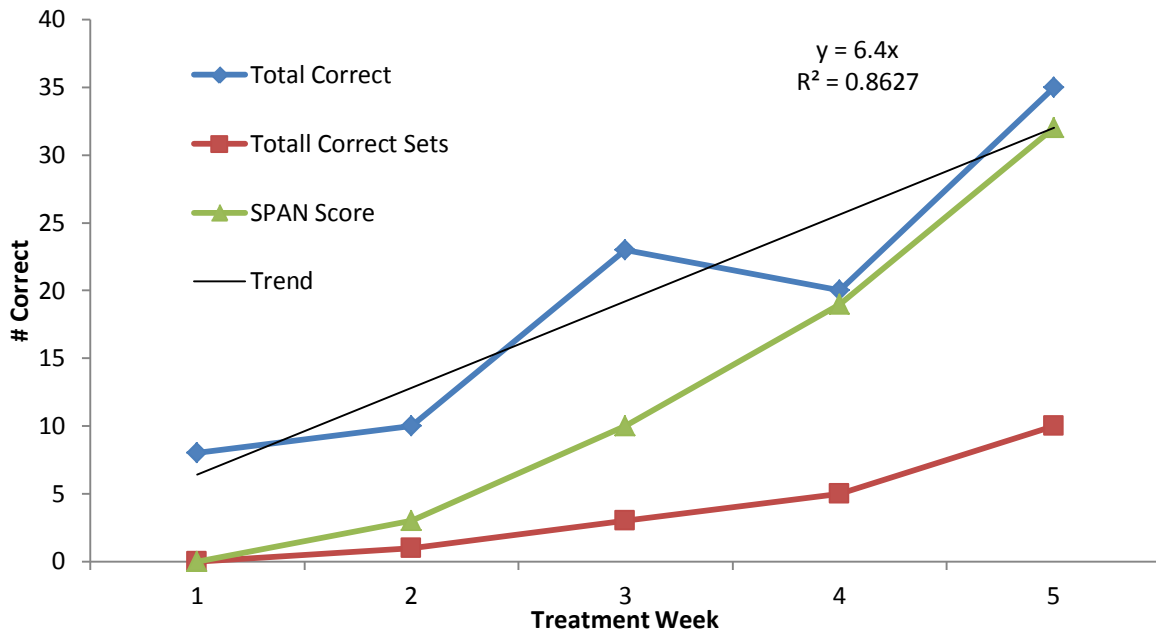
Figure 4.5. Participant 4's correctness data for the working memory treatment phase. (Increase indicates improved performance on working memory training tasks.)

For each graph representing working memory training scores the trend and variability are analyzed. Figure 4.5 shows values of correctness and SPAN scores over the five weeks of the intervention phase. The data points of the treatment indicate a small variability, a large upward trend, and a trend line with a large effect (R^2=.86). This trend line indicated that participant 4's working memory training scores were greatly improving over time.

Figure 4.6 shows values of error over the five weeks of the intervention phase. The data points of the intervention phase indicated a low variability, a large downward trend, and a trend line with a large effect (R^2=.88). This trend line indicated that participant 4's working memory training errors were greatly decreasing over time.
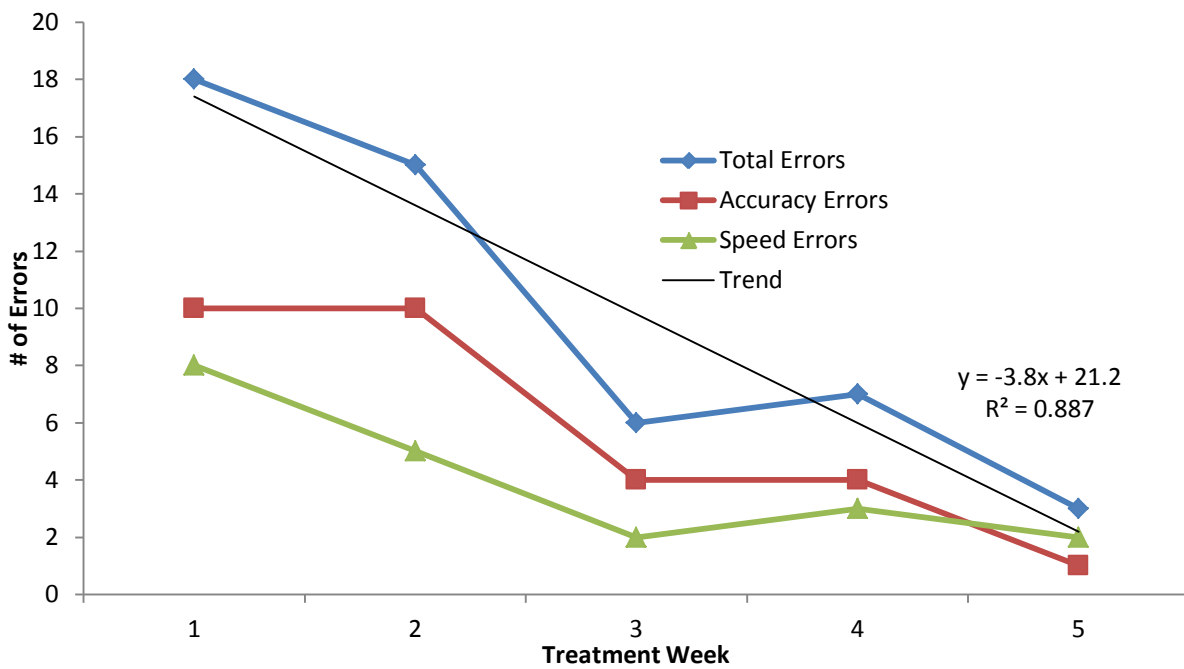
Figure 4.6. Participant 4's error data for the working memory treatment phase. (Decrease indicates improved performance on working memory training tasks.)
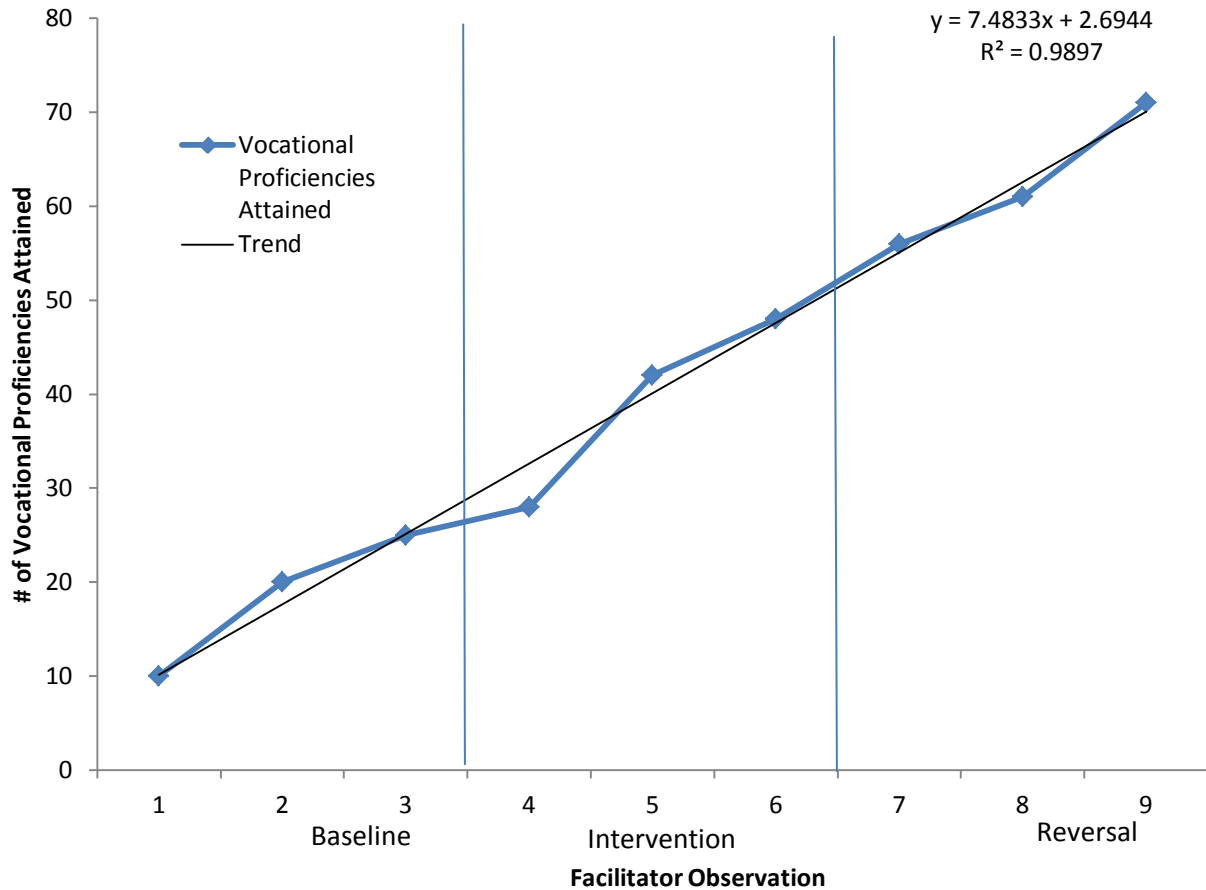
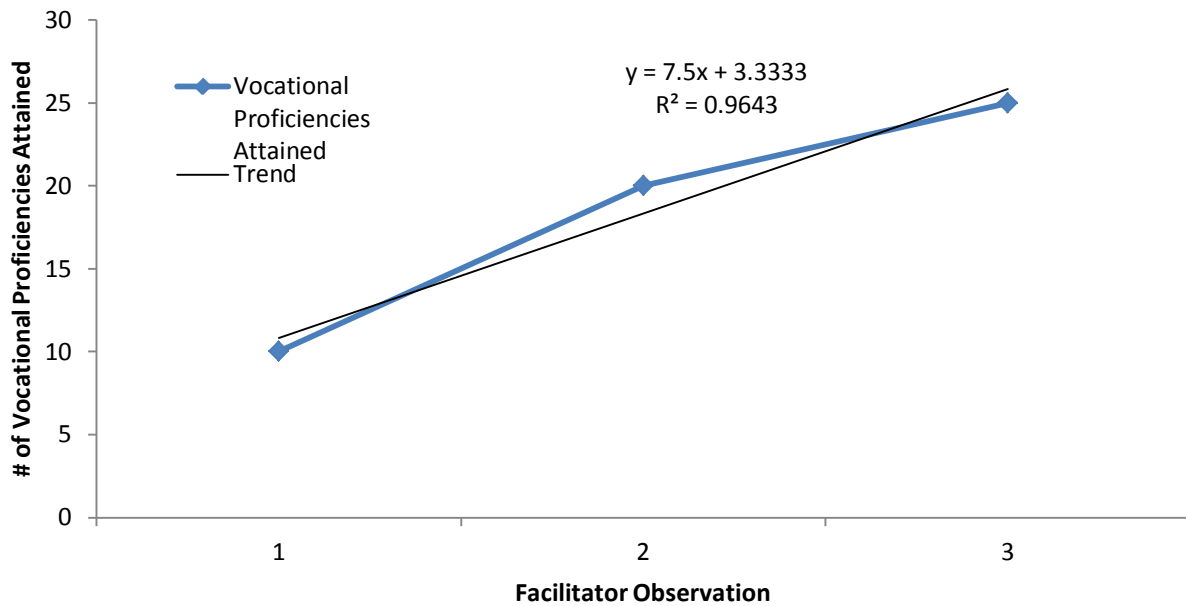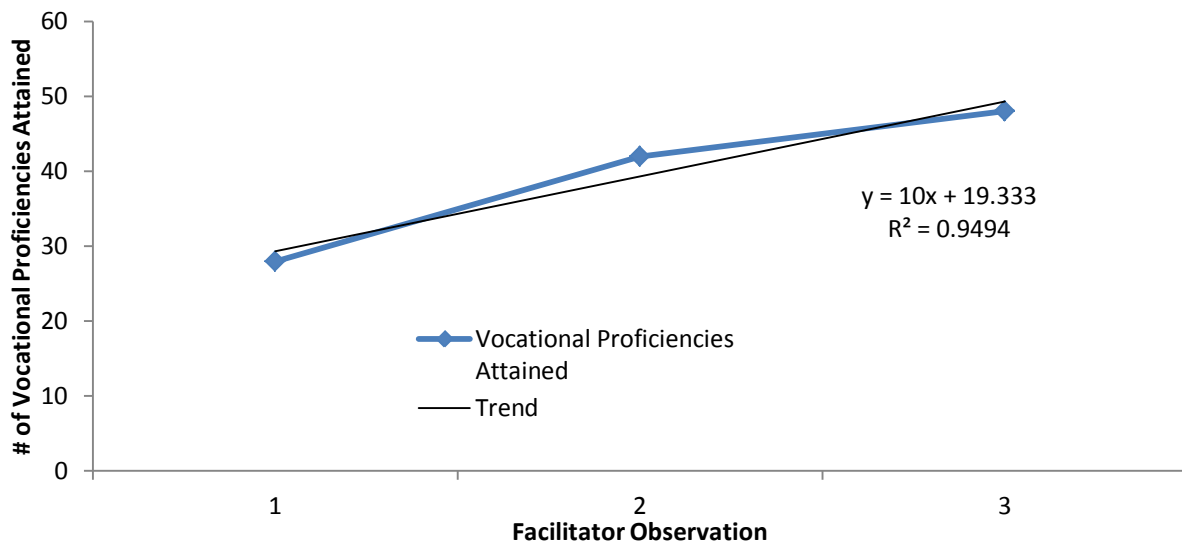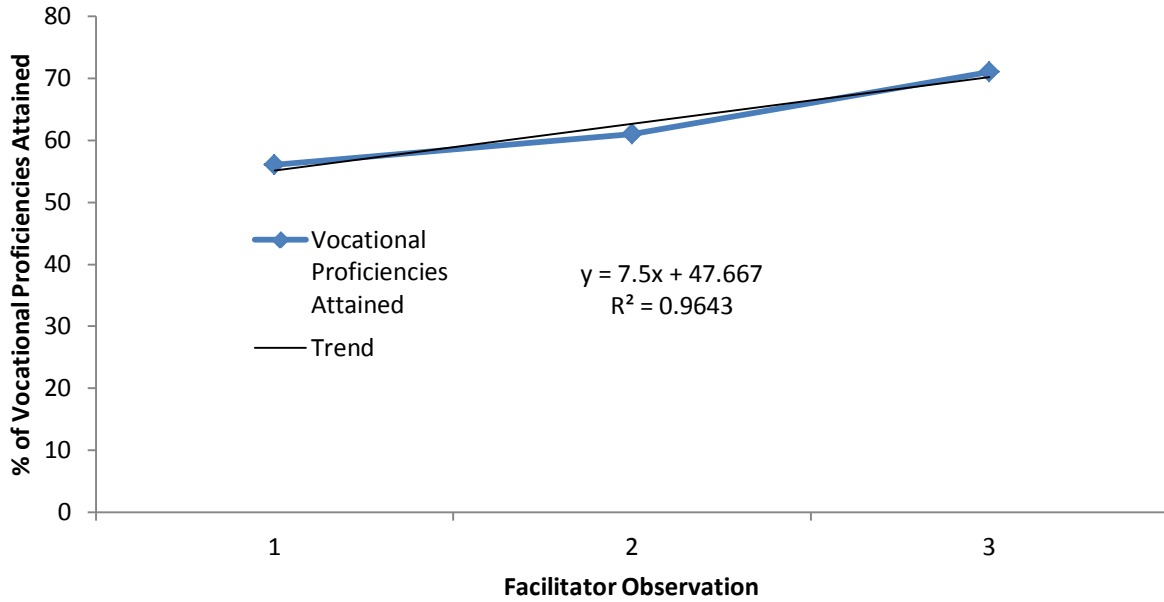*Figure 4.7.* Participant 4's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TAR.)

Figure 4.7 represents the correct number of vocational proficiencies attained for each individual over the course of the baseline, treatment, and reversal phases. The number of vocational proficiencies attained should increase over time. Once a participant's evaluation indicates they have met a standard in vocational progress it will stay attained. Therefore visual analysis of levels between phases was conducted through examination of each phase's slope and mean.

Visual analysis of trend was also conducted by examining the least squares regression. The trend data, shown in Figure 4.7, indicated an upward movement through visual analysis.

When calculating the least squares regression, a very strong relationship (R^2=0.98) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 4's TABE scores indicated a very small amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line.

$$y = 7.5x + 3.3333$$
$$R^2 = 0.9643$$

Figure 4.8. Participant 4's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline phase.

For each individual phase the level, trend, and variability is analyzed. Figure 4.8 shows TAR data for the baseline phase. The data points of the baseline phase indicate a small variability, an upward trend, a slope of 7.5, and a trend line with a large effect (R^2=.96). This trend line indicated that participant 4's TAR scores were improving without intervention over time.

Figure 4.9 shows TAR data for the intervention phase. The data points of the intervention phase indicated a low variability, an upward trend, a slope of 10, and a trend line with a large

effect (R^2=.95). This trend line indicated that participant 4's TAR scores were still trending upward with intervention over time.

Figure 4.10 shows TAR data for the reversal phase. The data for the reversal phase indicated a low variability, an upward trend, a slope of 7.5, and a trend line with a large effect (R^2=.96). This trend line indicated that participant 4's TAR scores were improving after the intervention over time.

Figure 4.9. Participant 4's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the intervention phase.

Figure 4.10. Participant 4's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the reversal phase.

Participant 5

Participant 5was evaluated using the TABE test of numerical reasoning and observed using TAR vocational progress monitoring survey. Participant 5 received five weeks of working memory training during the intervention phase.
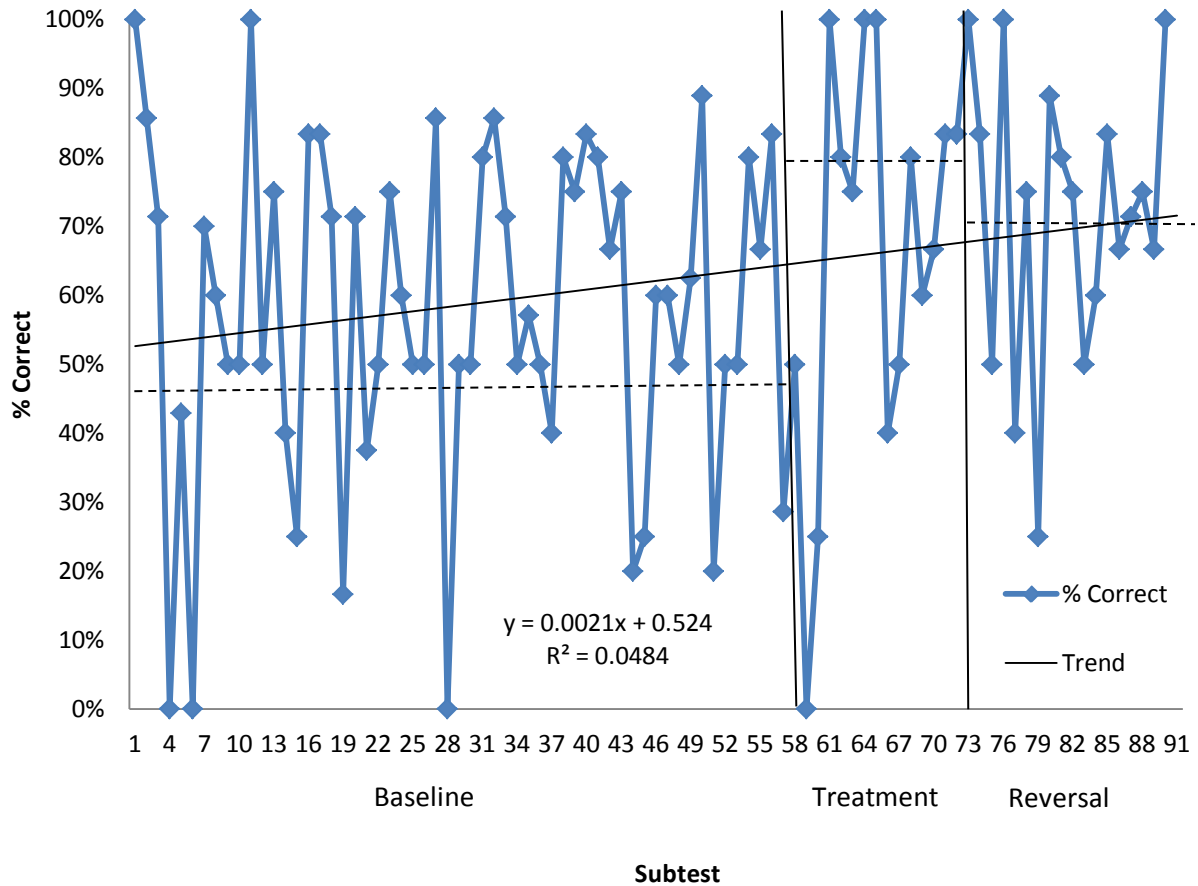
Figure 5.1. Participant 5's correctness on TABE tests of mathematics during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

Figure 5.1 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 5.1 provides a graphical representation of the observed TABE scores for participant 5 across all phases of the study. The visual analysis of levels between phases was conducted through examination of each phase's mean. As is evident from the graph, the mean of each phase (shown by the dashed black line) increased over the study. In Phase 1, the mean was 56%; in Phase 2, the mean was 77%, and in Phase 3, the mean was 70%. The increase in mean over time showed that participant 5's percentage of correctness on the TABE exam increased.

Visual analysis of trend was also conducted by examining the least squares regression. The trend is the slope and magnitude of the data that is described qualitatively. The trend data, shown in Figure 5.1, indicated an upward movement through visual analysis. When calculating the least squares regression, a small to medium relationship (R^2=0.04) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 5's TABE scores indicated a large amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation was calculated to show the dispersion from the average. Participant 5's standard deviation for the entire experiment was 24.9%(σ=.249, σ^2=.062).
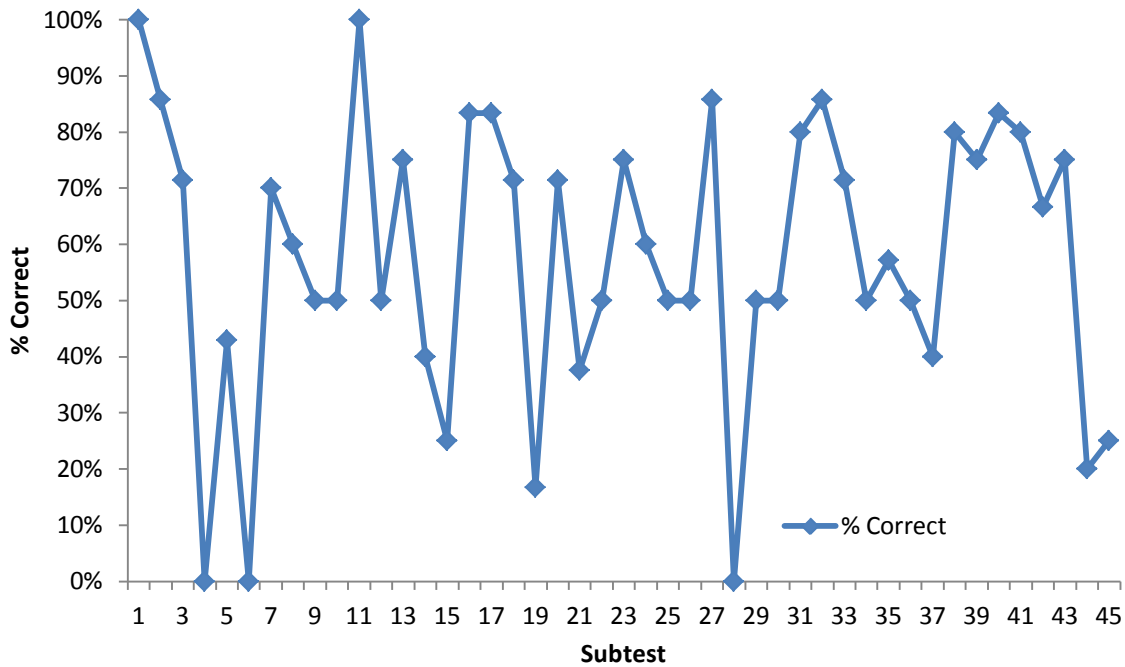
Figure 5.2. Participant 5's correctness trend for the TABE during the baseline phase.

For each individual phase the level and variability was analyzed. Figure 5.2 shows TABE data for the baseline phase. The data points of the baseline phase indicate a mean of 56% and a standard deviation of 25.2% ($\sigma=.252$, $\sigma^2=.064$). Figure 5.3 shows TABE data for the intervention phase. The data points of the intervention phase indicated a mean of 77% and a standard deviation of 19.8% ($\sigma=.198$, $\sigma^2=.039$). Figure 5.4 shows TABE data for the reversal phase. The data for the reversal phase indicated a mean of 70% and a standard deviation of 20.6% ($\sigma=.206$, $\sigma^2=.042$). This trend line indicated that participant 5's TABE scores were improving after the intervention over time but still were variable.
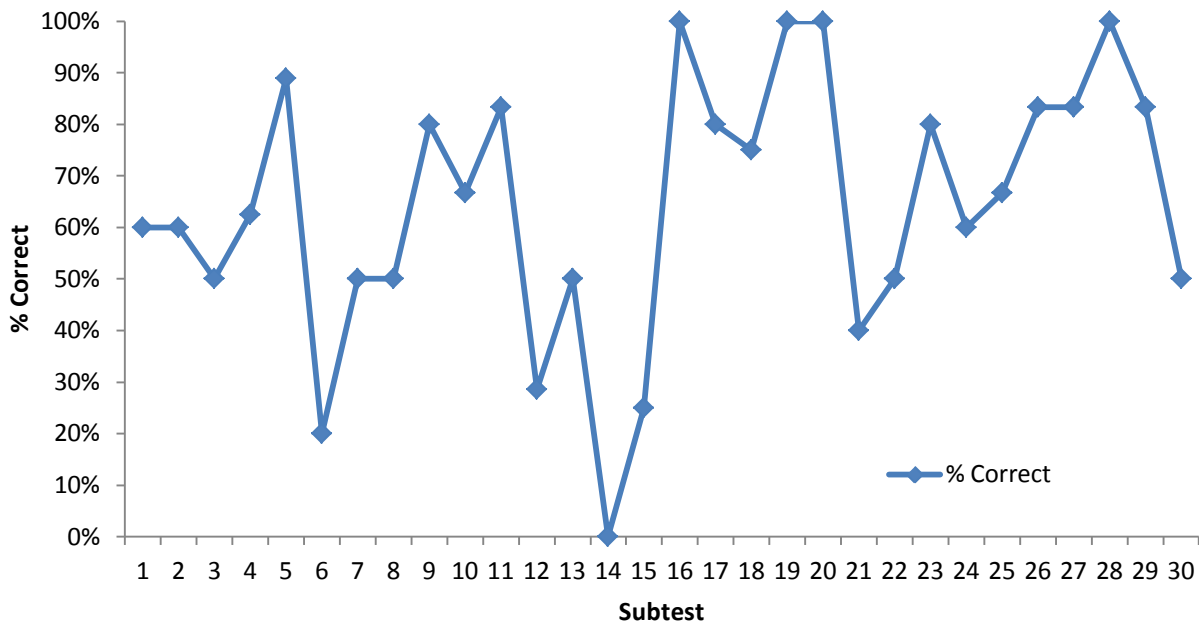
Figure 5.3. Participant 5's correctness trend for the TABE during the treatment phase.
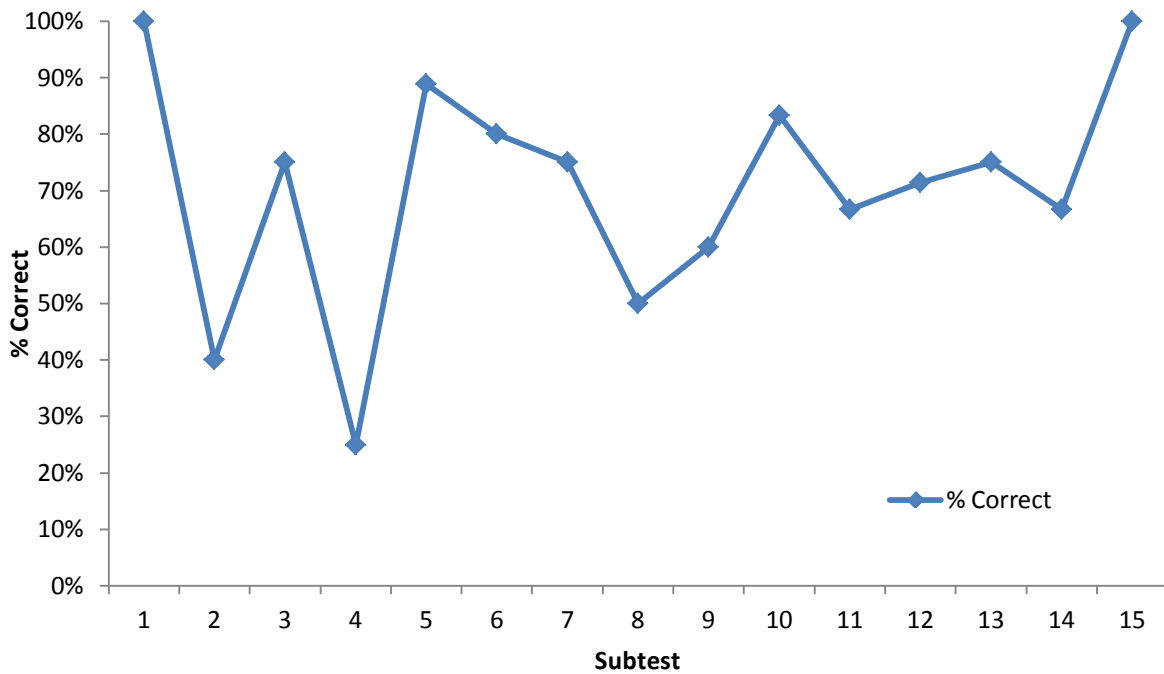
Figure 5.4. Participant 5's correctness trend for the TABE during the reversal phase.
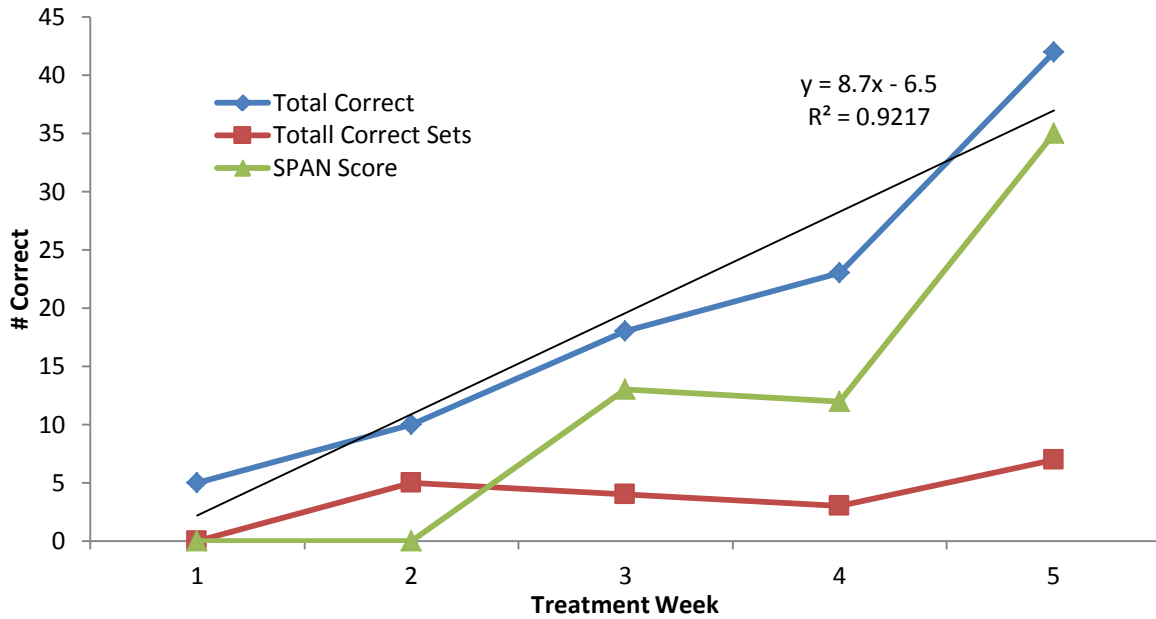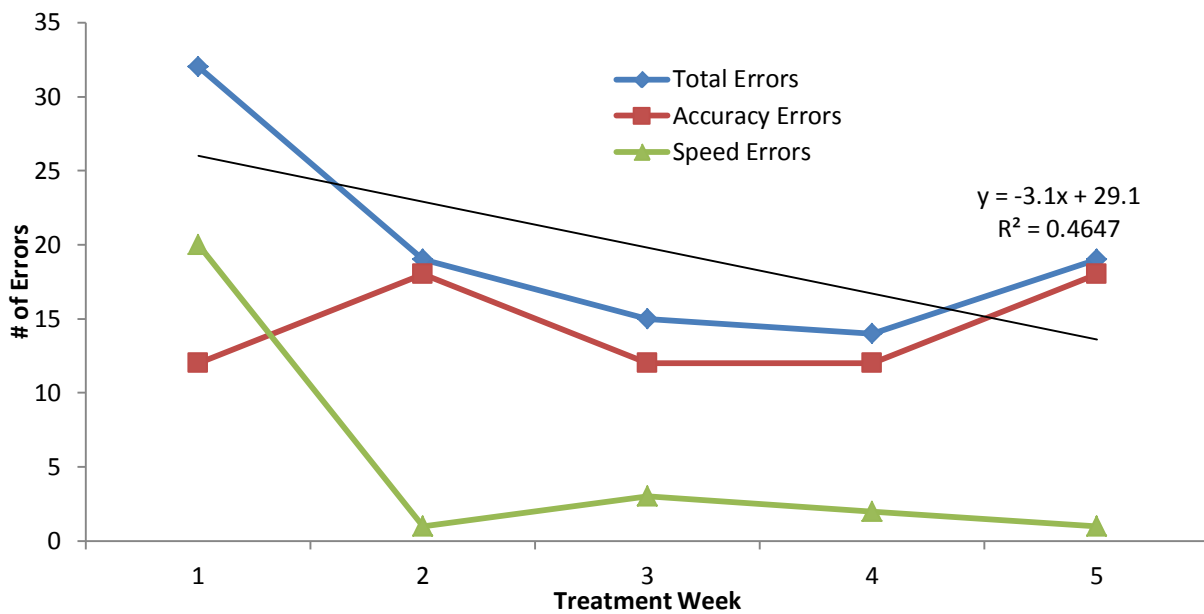

Figure 5.5. Participant 5's correctness data for the working memory treatment phase. (Increase

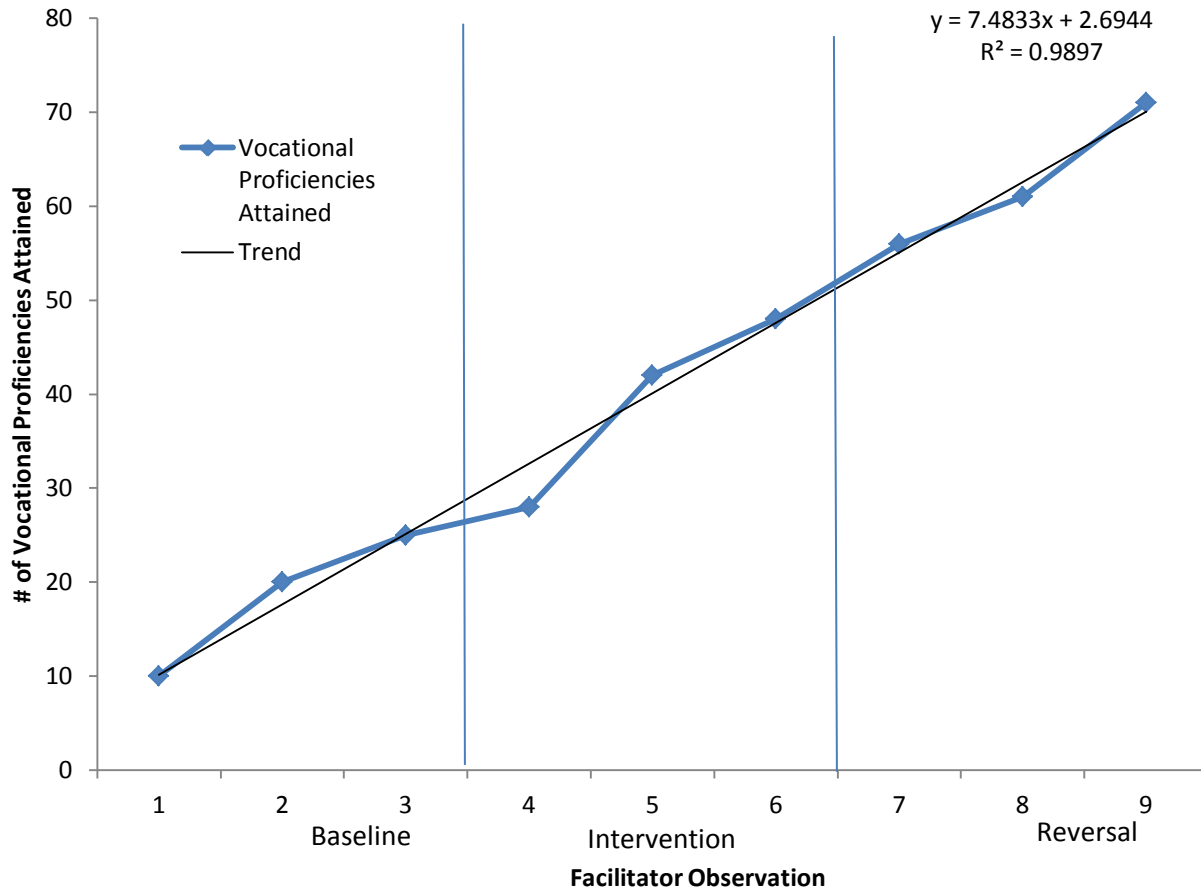indicates improved performance on working memory training tasks.)

For each graph representing working memory training scores the trend and variability are analyzed. Figure 5.5 shows values of correctness and SPAN scores over the five weeks of the intervention phase. The data points of the treatment indicate a small variability, a large upward trend, and a trend line with a large effect (R^2=.92). This trend line indicated that participant 5's working memory training scores were greatly improving over time.

Figure 5.6 shows values of error over the five weeks of the intervention phase. The data points of the intervention phase indicated a medium variability, a large downward trend, and a trend line with a large effect (R^2=.46). This trend line indicated that participant 5's working memory training errors were decreasing over time.

Figure 5.6. Participant 5's error data for the working memory treatment phase. (Decrease indicates improved performance on working memory training tasks.)

Figure 5.7. Participant 5's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TAR.)

Figure 5.7 represents the correct number of vocational proficiencies attained for each individual over the course of the baseline, treatment, and reversal phases. The number of vocational proficiencies attained should increase over time. Once a participant's evaluation indicates they have met a standard in vocational progress it will stay attained. Therefore visual analysis of levels between phases was conducted through examination of each phase's slope and mean.

Visual analysis of trend was also conducted by examining the least squares regression. The trend data, shown in Figure 5.7, indicated an upward movement through visual analysis.

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When calculating the least squares regression, a very strong relationship (R^2=0.99) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 5's TABE scores indicated a very small amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line.
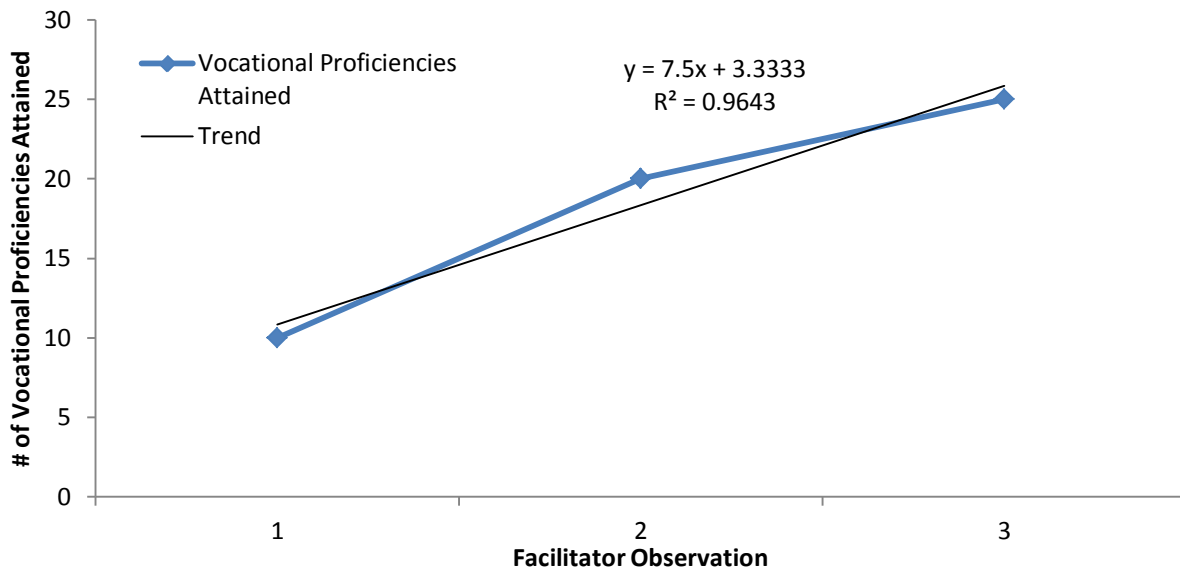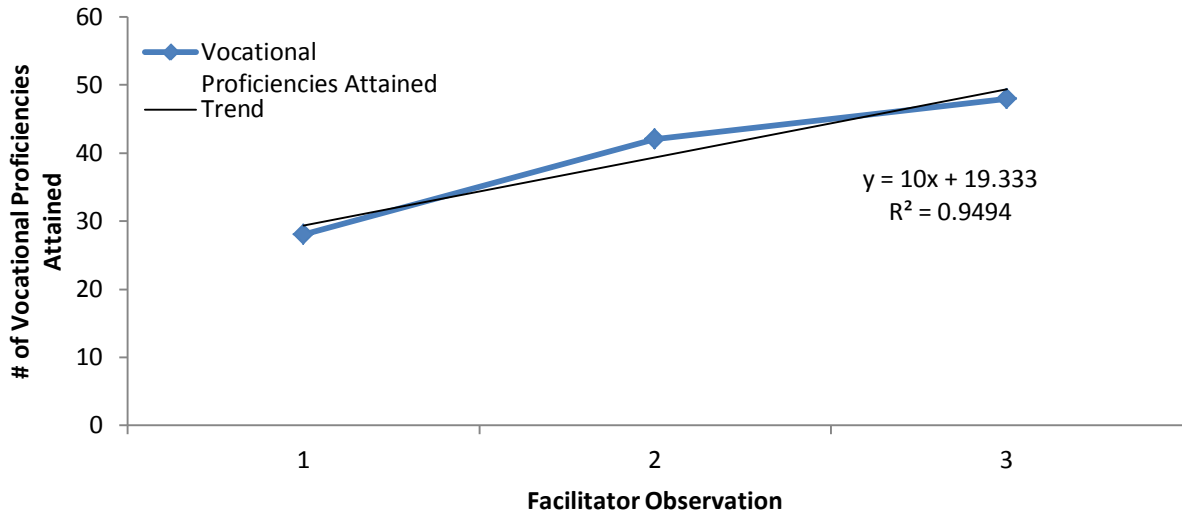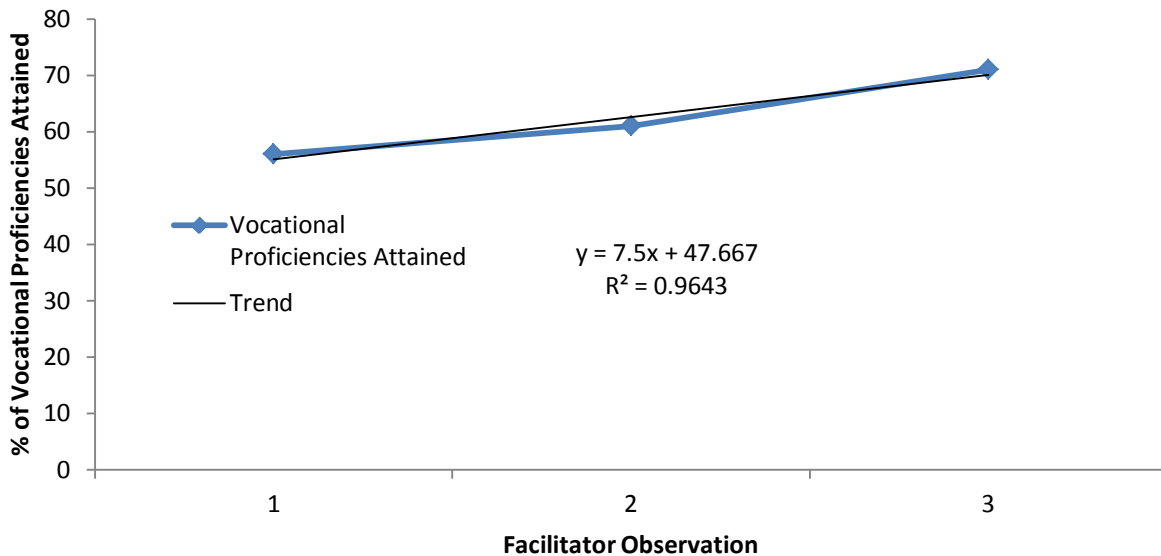

Figure 5.8. Participant 5's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline phase.

For each individual phase the level, trend, and variability is analyzed. Figure 5.8 shows TAR data for the baseline phase. The data points of the baseline phase indicate a small variability, an upward trend, a slope of 7.5, and a trend line with a large effect (R^2=.96). This trend line indicated that participant 5's TAR scores were improving without intervention over time.

Figure 5.9 shows TAR data for the intervention phase. The data points of the intervention phase indicated a low variability, an upward trend, a slope of 10, and a trend line with a large

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effect (R^2=.95). This trend line indicated that participant 5's TAR scores were still trending

upward with intervention over time but with a larger slope than the baseline phase.

Figure 5.10 shows TAR data for the reversal phase. The data for the reversal phase

indicated a low variability, an upward trend, a slope of 7.5, and a trend line with a large effect

(R^2=.96). This trend line indicated that participant 5's TAR scores were improving after the

intervention over time but with a smaller slope than the intervention phase.

Figure 5.9. Participant 5's number of vocational skills attained through the TAR vocational

progress monitoring evaluation during the intervention phase.

Figure 5.10. Participant 5's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the reversal phase.

Participant 6

Participant 6 was evaluated using the TABE test of numerical reasoning and observed using the TAR vocational progress monitoring survey. Participant 6 received five weeks of working memory training during the intervention phase.
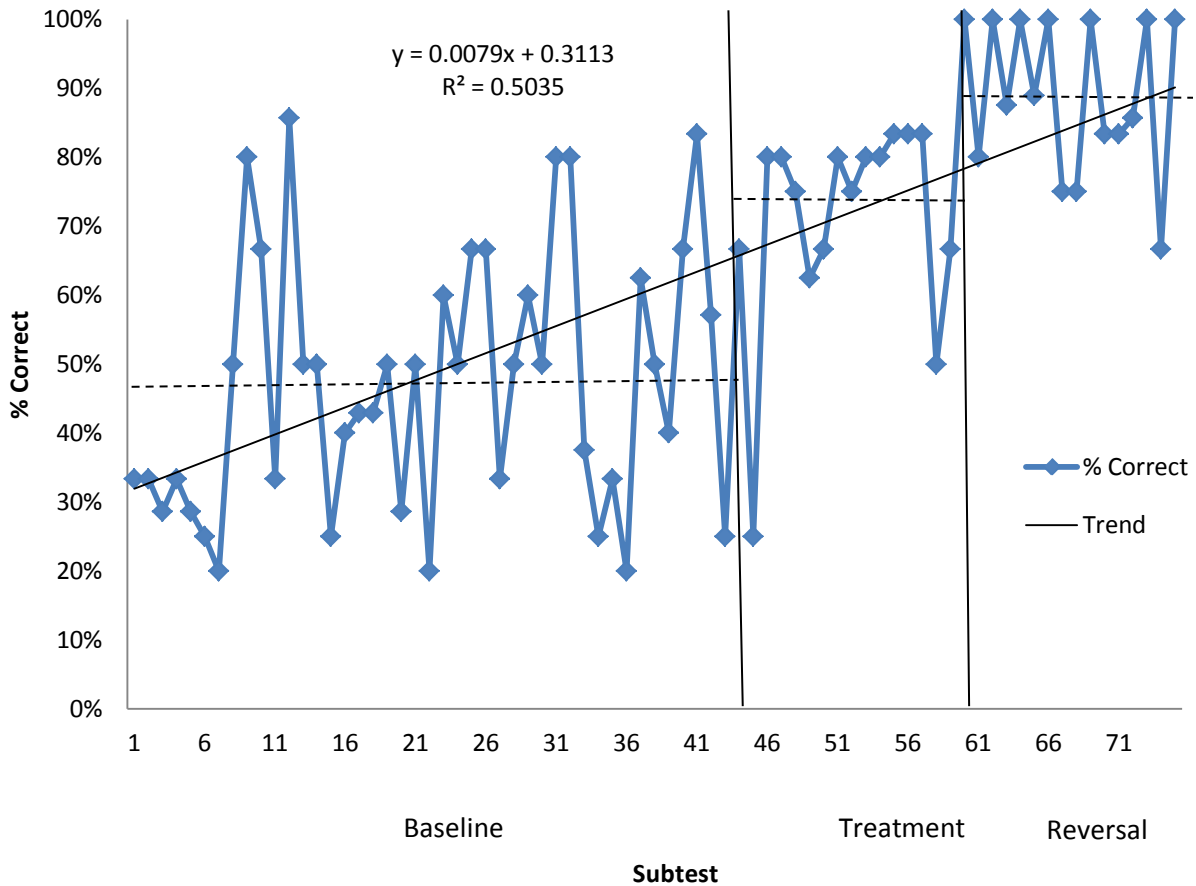

Figure 6.1. Participant 6's correctness on TABE tests of mathematics during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

Figure 6.1 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 6.1 provides a graphical representation of the observed TABE scores for participant 6 across all phases of the study. The visual analysis of levels between phases was conducted through examination of each phase's mean. As is evident from the graph, the mean of each phase (shown by the dashed black line) increased over the study. In Phase 1, the mean was 47%, in Phase 2, the mean was 76%, and in Phase 3, the mean was 88%. The increase in mean over time showed that participant 6's percentage of correctness on the TABE exam increased.

Visual analysis of trend was also conducted by examining the least squares regression. The trend is the slope and magnitude of the data that is described qualitatively. The trend data, shown in Figure 6.1, indicated an upward movement through visual analysis. When calculating the least squares regression, a large relationship (R^2=0.50) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 6's TABE scores indicated a large amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation was calculated to show the dispersion from the average. Participant 6's standard deviation for the entire experiment was 24.1%(σ=.241, σ^2=.058).
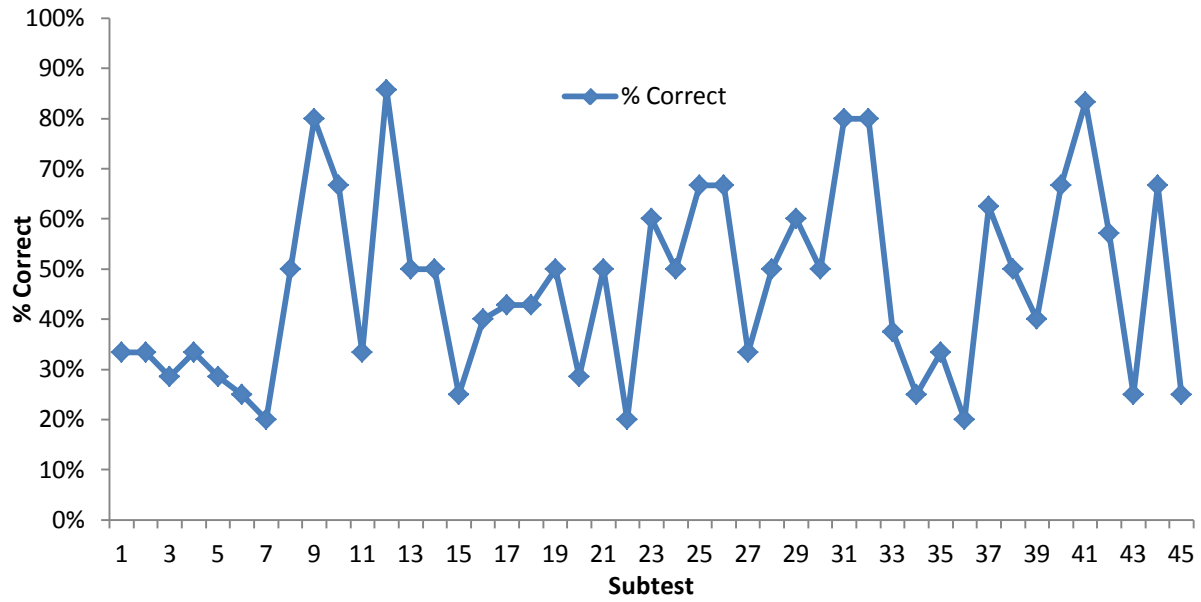
Figure 6.2. Participant 6's correctness trend for the TABE during the baseline phase.

For each individual phase the level and variability was analyzed. Figure 6.2 shows TABE data for the baseline phase. The data points of the baseline phase indicate a mean of 47% and a standard deviation of 18.9%(σ=.189, σ^2=.035). Figure 6.3 shows TABE data for the intervention phase. The data points of the intervention phase indicated a mean of 76% and a standard deviation of 11.5%(σ=.115, σ^2=.013). Figure 6.4 shows TABE data for the reversal phase. The data for the reversal phase indicated a mean of 88% and a standard deviation of 11.2%(σ=.112, σ^2=.013). This trend line indicated that participant 6's TABE scores were improve from the previous phases and less variable than the baseline.
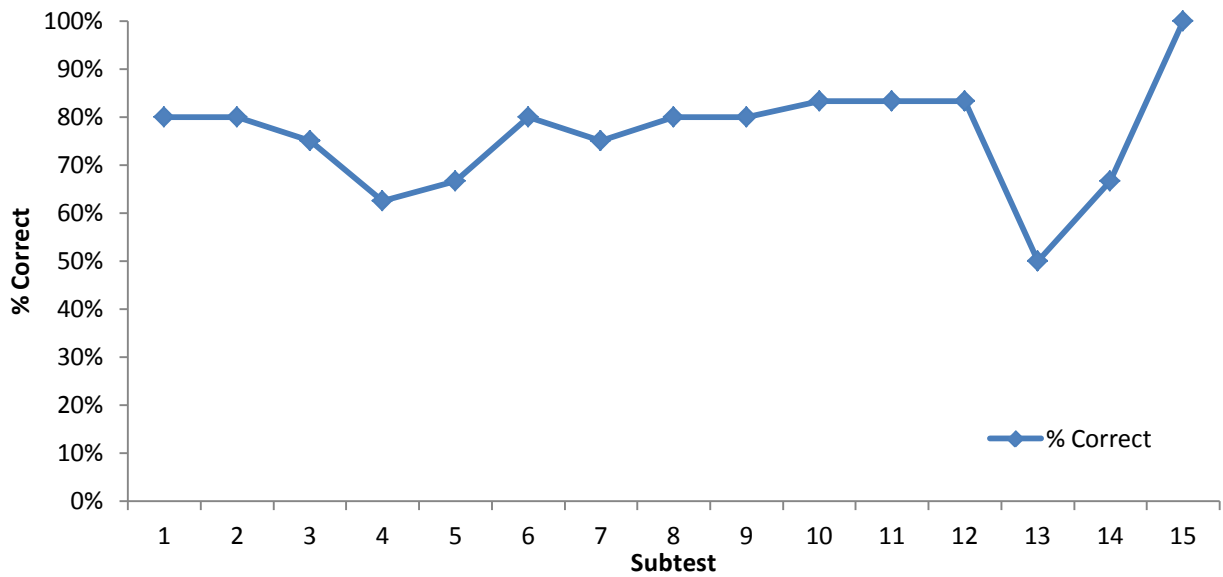
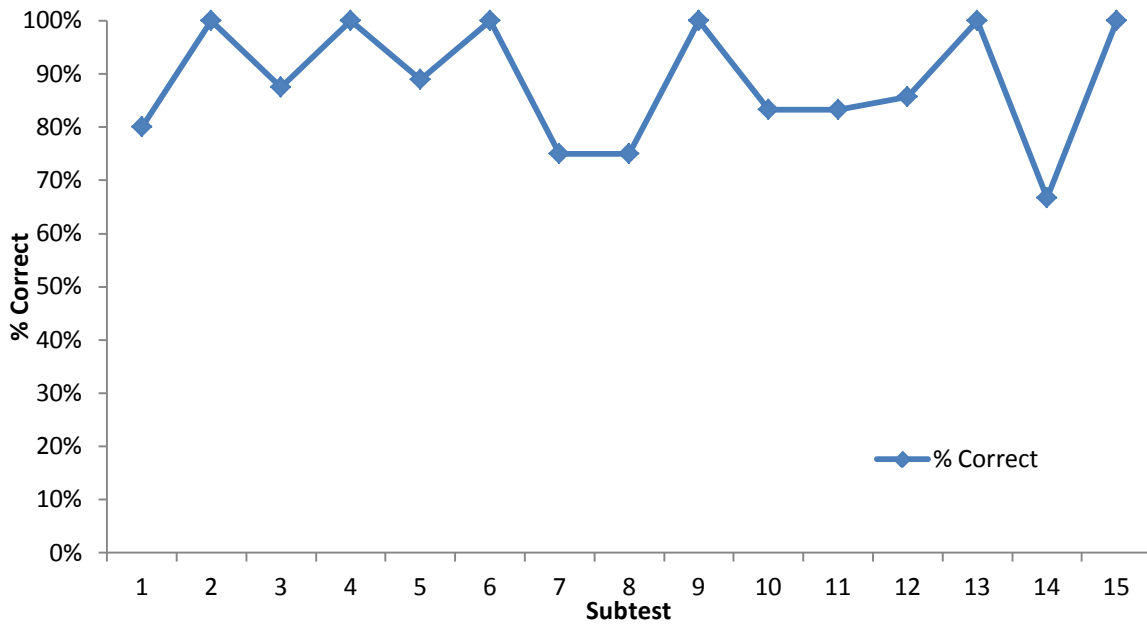*Figure 6.3.* Participant 6's correctness trend for the TABE during the treatment phase.

Figure 6.4. Participant 6's correctness trend for the TABE during the reversal phase.
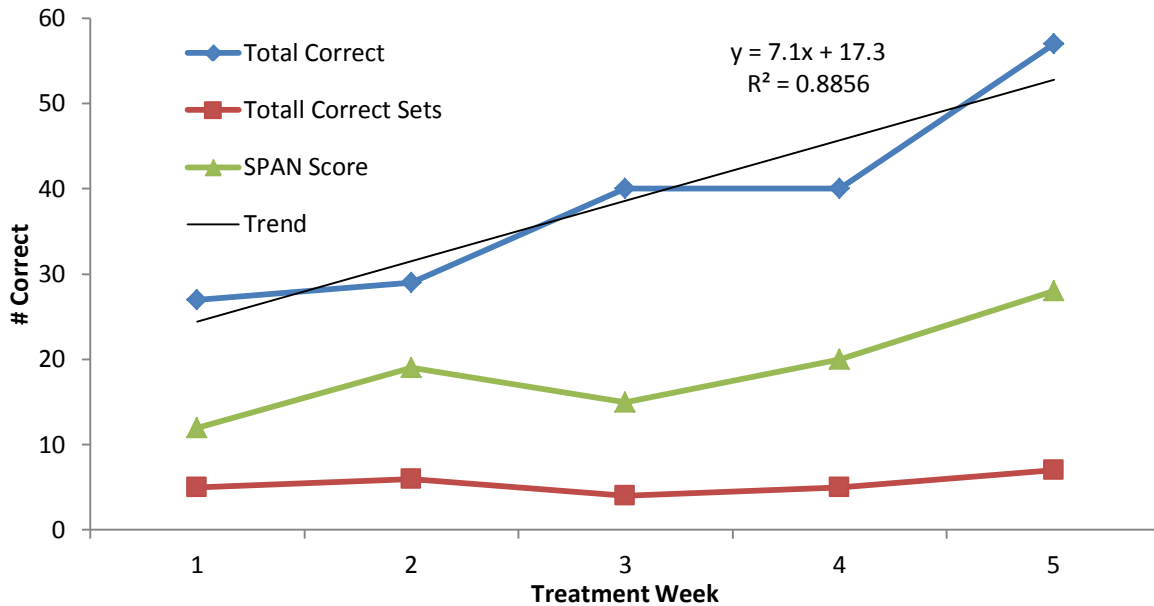
Figure 6.5. Participant 6's correctness data for the working memory treatment phase. (Increase indicates improved performance on working memory training tasks.)

For each graph representing working memory training scores the trend and variability are analyzed. Figure 6.5 shows values of correctness and SPAN scores over the five weeks of the intervention phase. The data points of the treatment indicate a small variability, a large upward trend, and a trend line with a large effect (R^2=.88). This trend line indicated that participant 6's working memory training scores were greatly improving over time.

Figure 6.6 shows values of error over the five weeks of the intervention phase. The data points of the intervention phase indicated a medium variability, a large downward trend, and a trend line with a large effect (R^2=.79). This trend line indicated that participant 6's working memory training errors were greatly decreasing over time.
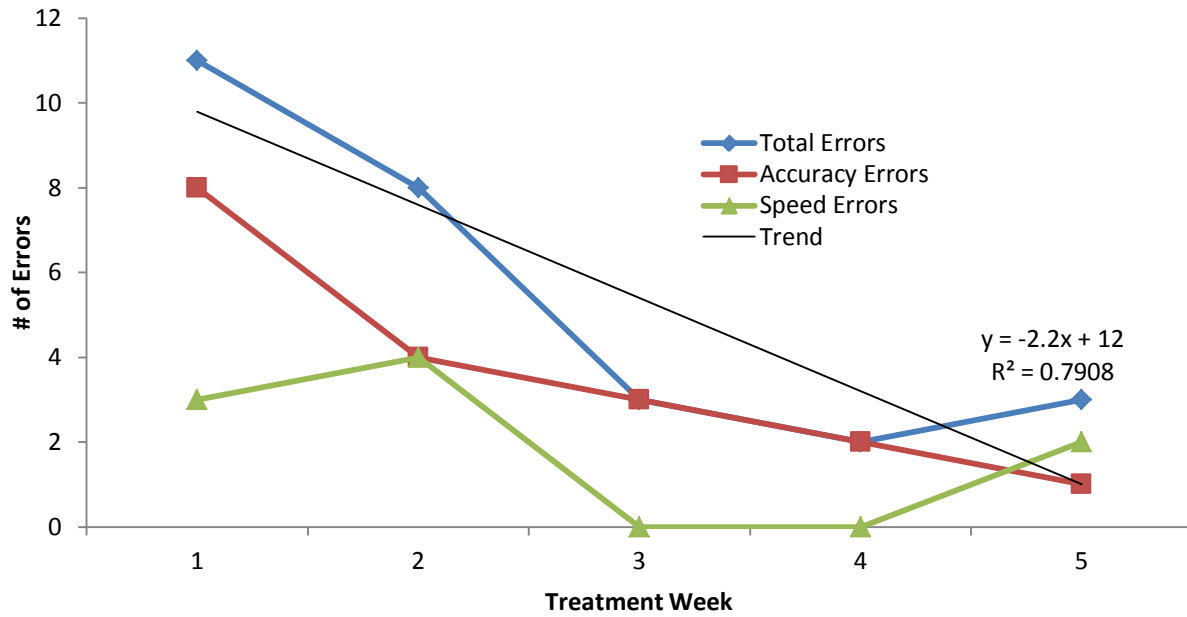
Figure 6.6. Participant 6's error data for the working memory treatment phase. (Decrease

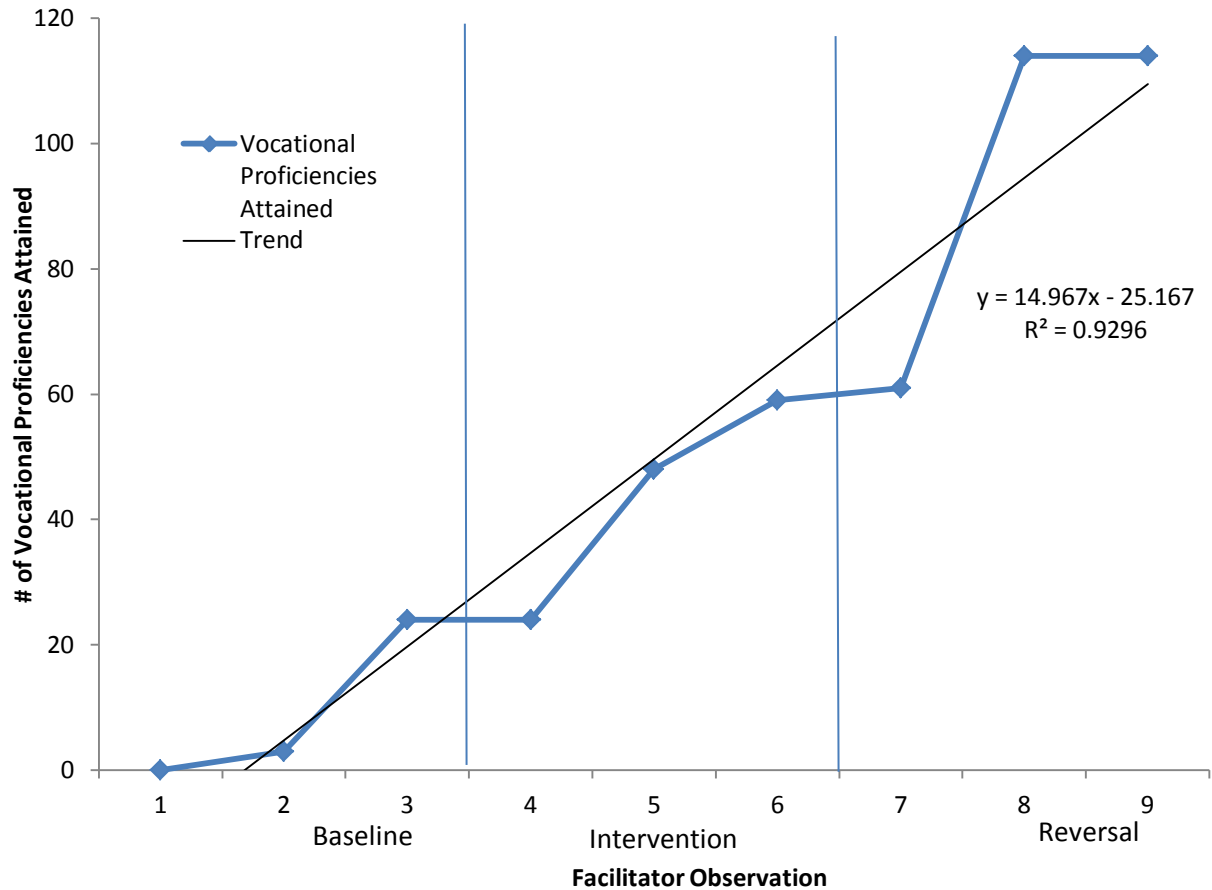indicates improved performance on working memory training tasks.)

Figure 6.7. Participant 6's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TAR.)

Figure 6.7 represents the correct number of vocational proficiencies attained for each individual over the course of the baseline, treatment, and reversal phases. The number of vocational proficiencies attained should increase over time. Once a participant's evaluation indicates they have met a standard in vocational progress it will stay attained. Therefore visual analysis of levels between phases was conducted through examination of each phase's slope and mean.

Visual analysis of trend was also conducted by examining the least squares regression. The trend data, shown in Figure 6.7, indicated an upward movement through visual analysis.

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When calculating the least squares regression, a very strong relationship (R^2=0.92) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 6's TABE scores indicated a very small amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line.
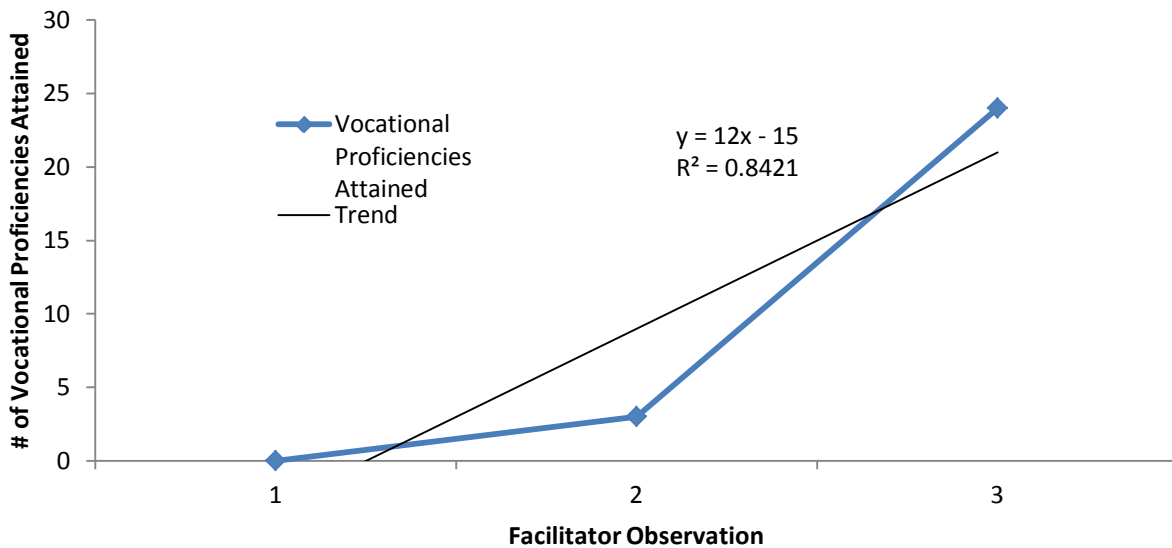

Figure 6.8. Participant 6's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline phase.

For each individual phase the level, trend, and variability is analyzed. Figure 6.8 shows TAR data for the baseline phase. The data points of the baseline phase indicate a small variability, an upward trend, a slope of 12, and a trend line with a large effect (R^2=.84). This trend line indicated that participant 6's TAR scores were improving without intervention over time.

Figure 6.9 shows TAR data for the intervention phase. The data points of the intervention phase indicated a low variability, an upward trend, a slope of 17.5, and a trend line with a large

effect (R^2=.96). This trend line indicated that participant 6's TAR scores were still trending upward with a larger slope than baseline during the intervention phase.

Figure 6.10 shows TAR data for the reversal phase. The data for the reversal phase indicated a low variability, an upward trend, a slope of 17.5, and a trend line with a large effect (R^2=.75). This trend line indicated that participant 6's TAR scores were still improving after the intervention and maintained an increased slope compared to the baseline phase.
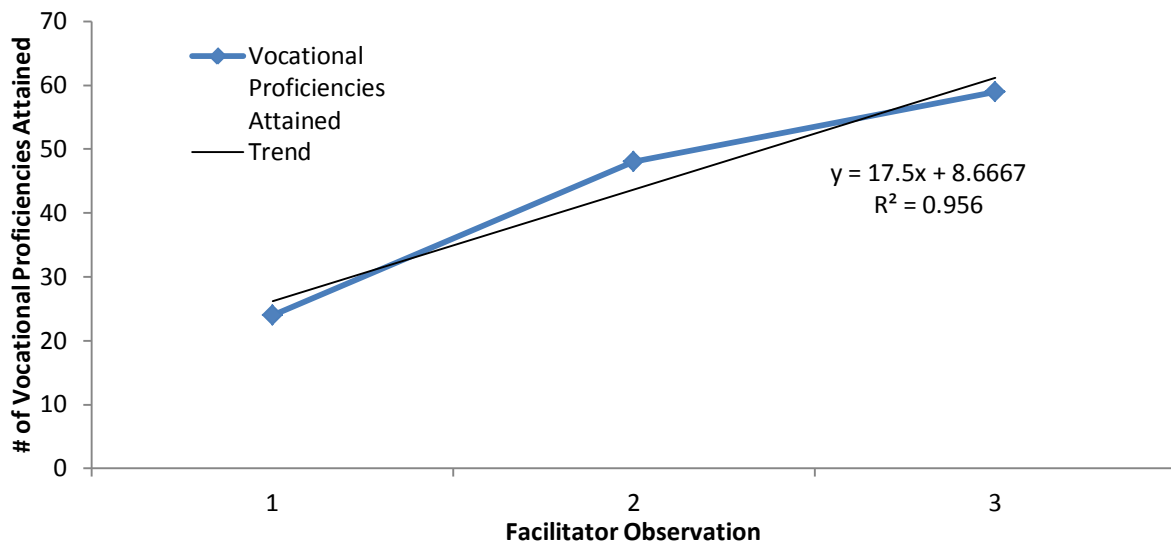

Figure 6.9. Participant 6's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the intervention phase.
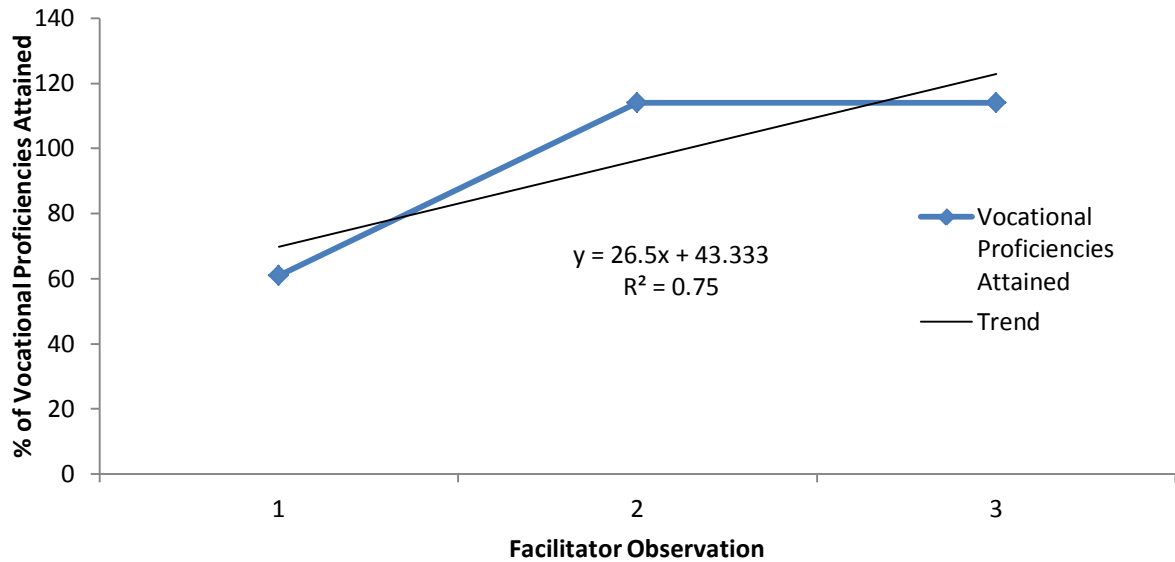
Figure 6.10. Participant 6's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the reversal phase.

Participant 7

Participant 7was evaluated using the TABE test of numerical reasoning and observed using TAR vocational progress monitoring survey. Participant 7 received five weeks of working memory training during the intervention phase.
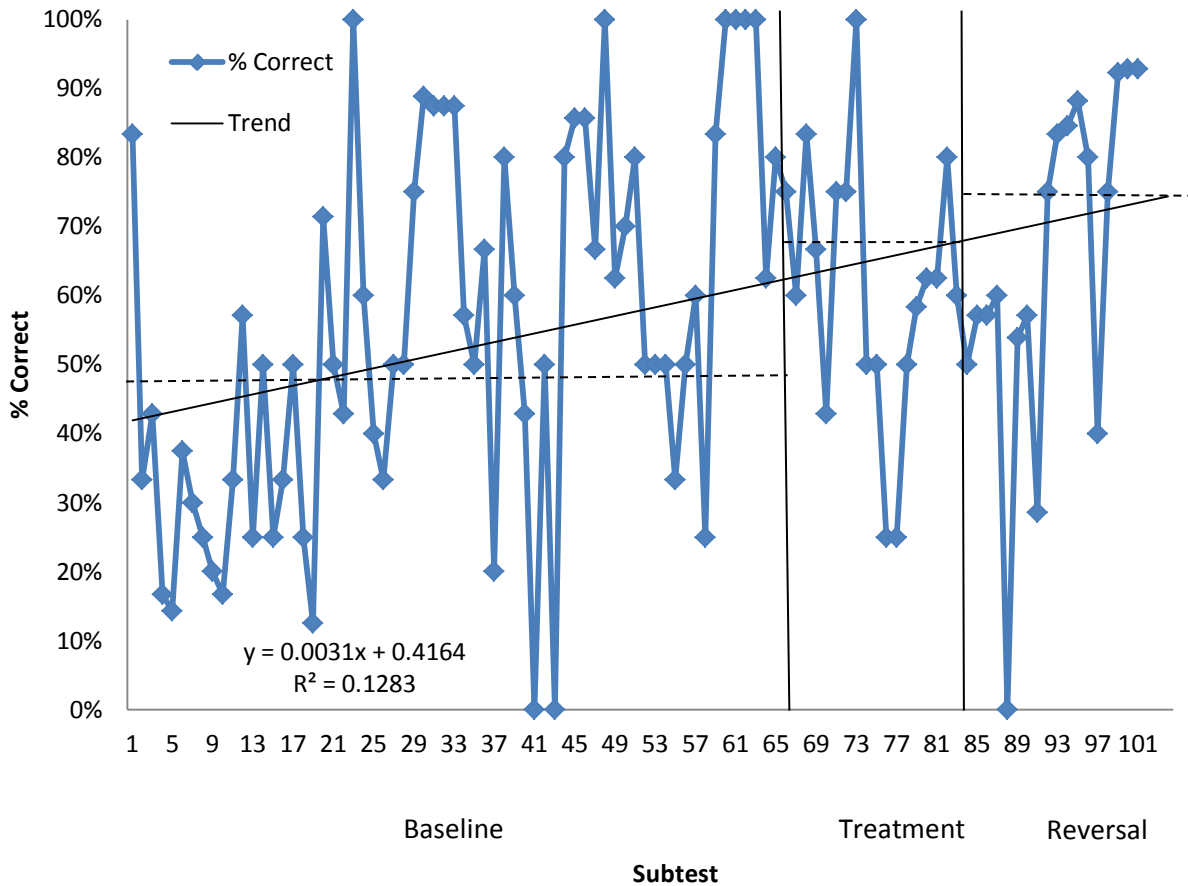
Figure 7.1. Participant 7's correctness on TABE tests of mathematics during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

Figure 7.1 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 7.1 provides a graphical representation of the observed TABE scores for participant 7 across all phases of the study. The visual analysis of levels between phases was conducted through examination of each phase's mean. As is evident from the graph, the mean of each phase (shown by the dashed black line) increased over the study. In Phase 1, the mean was 49%; in Phase 2, the mean was 61%, and in Phase 3, the mean was 71%. The increase in mean over time showed that participant 7's percentage of correctness on the TABE exam increased.

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Visual analysis of trend was also conducted by examining the least squares regression. The trend is the slope and magnitude of the data that is described qualitatively. The trend data, shown in Figure 7.1, indicated an upward movement through visual analysis. When calculating the least squares regression, a small to medium relationship (R^2=0.13) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 7's TABE scores indicated a large amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation was calculated to show the dispersion from the average. Participant 7's standard deviation for the entire experiment was 22.2%(σ=.222, σ^2=.049).
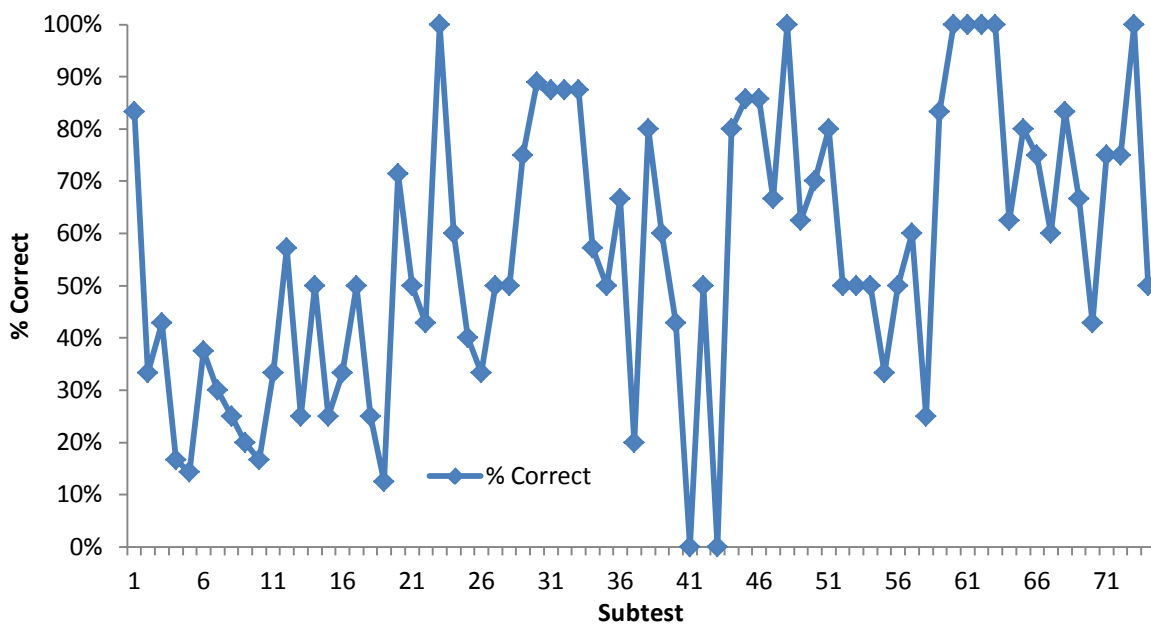

Figure 7.2. Participant 7's correctness trend for the TABE during the baseline phase.

For each individual phase the level and variability is analyzed. Figure 7.2 shows TABE data for the baseline phase. The data points of the baseline phase indicate a mean of 49% and a

standard deviation of 19.9%(σ=.199, σ^2=.040). Figure 7.3 shows TABE data for the

intervention phase. The data points of the intervention phase indicated a mean of 61% and a

standard deviation of 13.7%(σ=.137, σ^2=.019). Figure 7.4 shows TABE data for the reversal

phase. The data for the reversal phase indicated a mean of 71% and a standard deviation of

9.3%(σ=.093, σ^2=.009). Participant 7's TABE scores were steadily improving after the

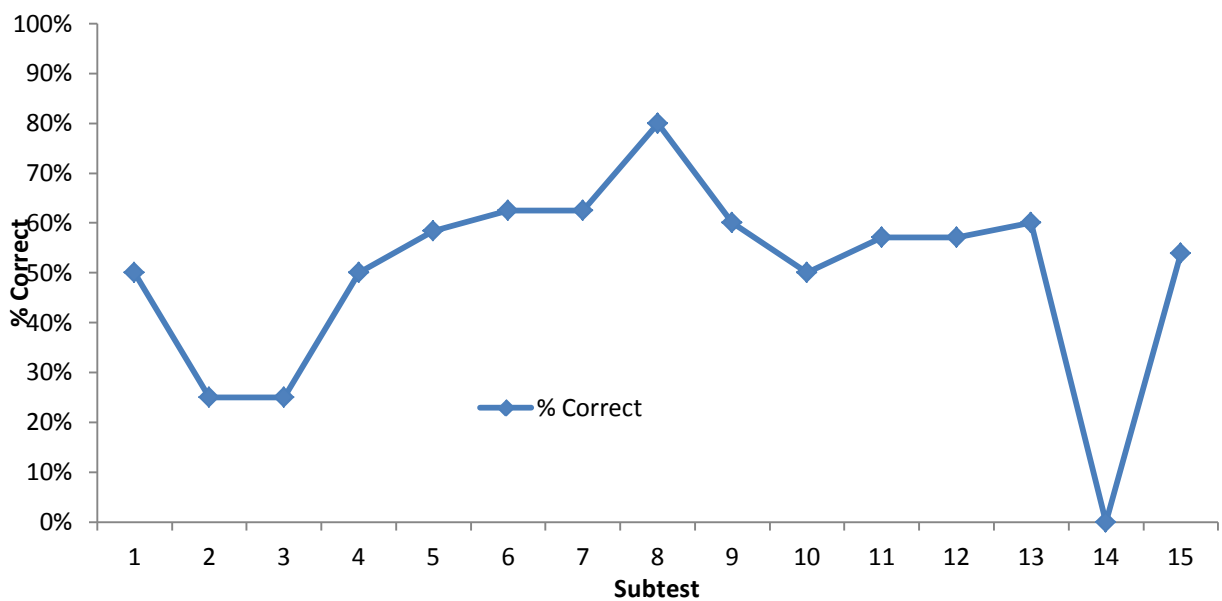intervention and had a reduced variability from baseline.

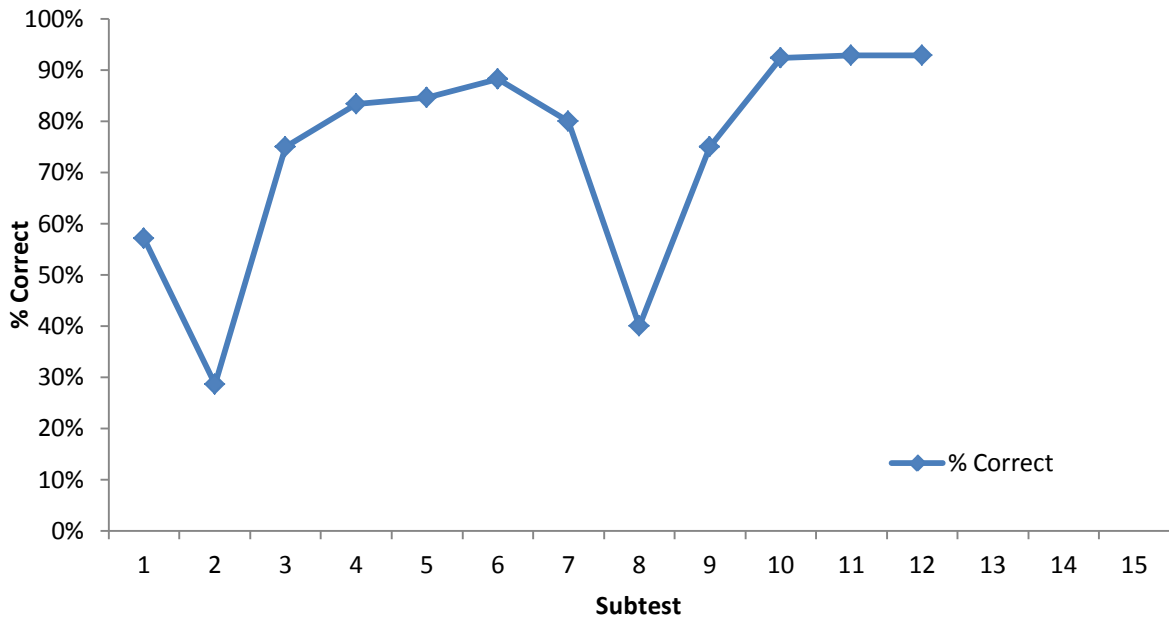*Figure 7.3.* Participant 7's correctness trend for the TABE during the treatment phase.

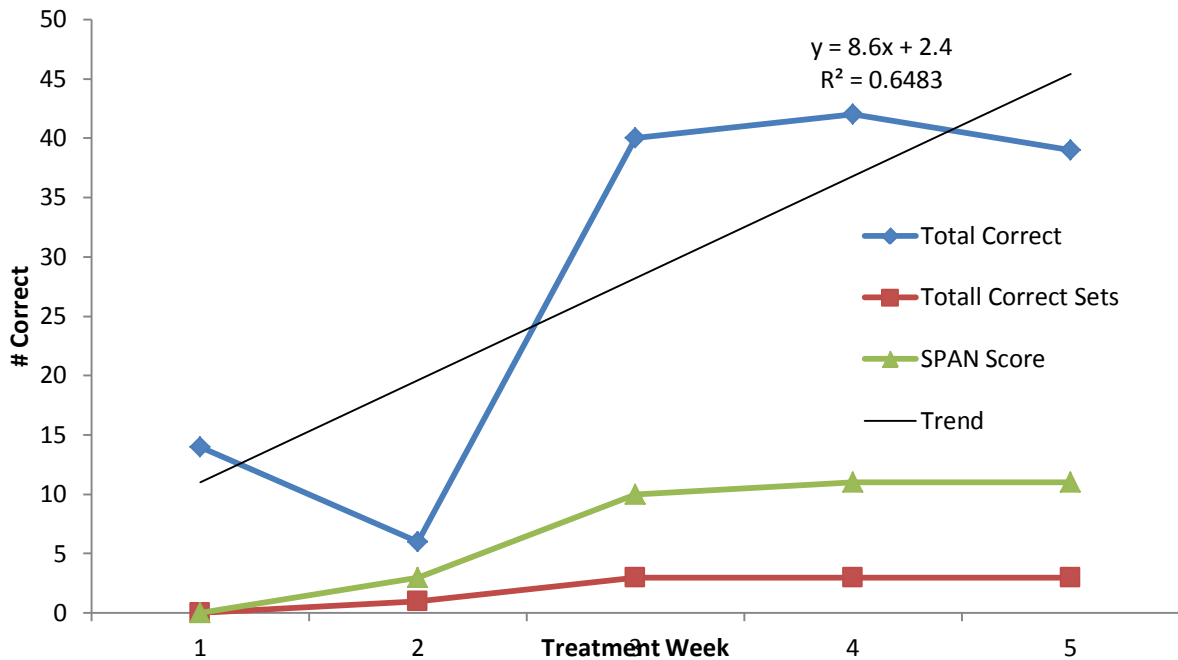*Figure 7.4.* Participant 7's correctness trend for the TABE during the reversal phase.

Figure 7.5. Participant 7's correctness data for the working memory treatment phase. (Increase indicates improved performance on working memory training tasks.)

For each graph representing working memory training scores the trend and variability are analyzed. Figure 7.5 shows values of correctness and SPAN scores over the five weeks of the intervention phase. The data points of the treatment indicate a moderate variability, a large upward trend, and a trend line with a large effect (R^2=.65). This trend line indicated that participant 7's working memory training scores were greatly improving over time.

Figure 7.6 shows values of error over the five weeks of the intervention phase. The data points of the intervention phase indicated a medium to low variability, a large downward trend, and a trend line with a large effect (R^2=.33). This trend line indicated that participant 7's working memory training errors were greatly decreasing over time.
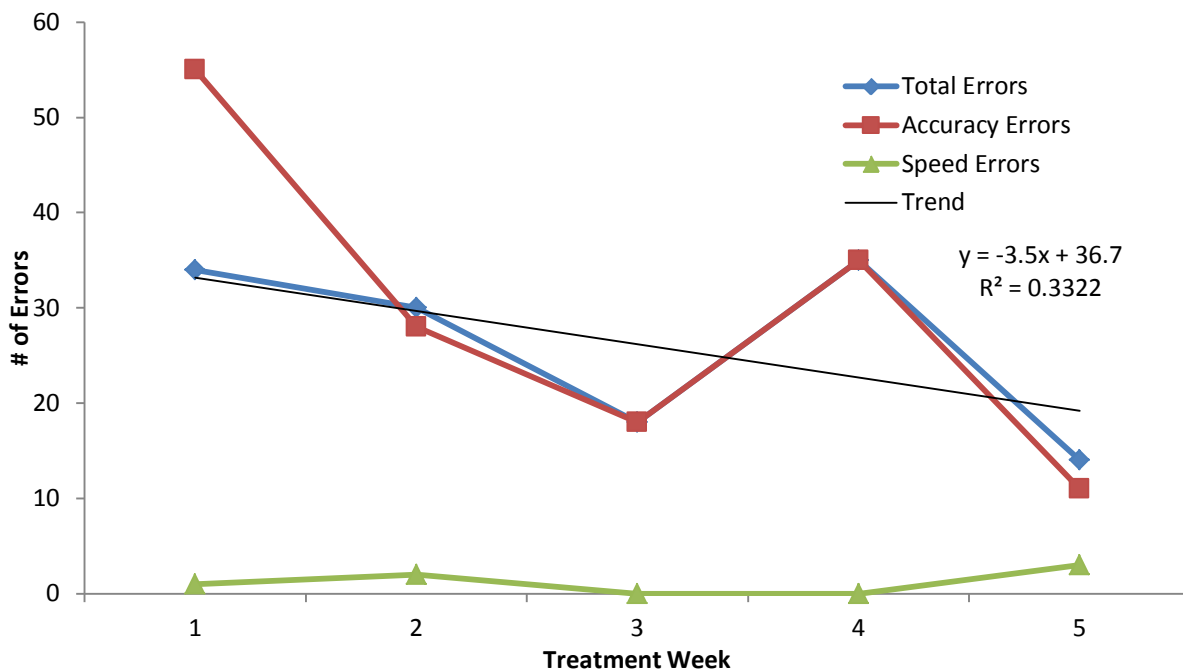

Figure 7.6. Participant 7's error data for the working memory treatment phase. (Decrease indicates improved performance on working memory training tasks.)
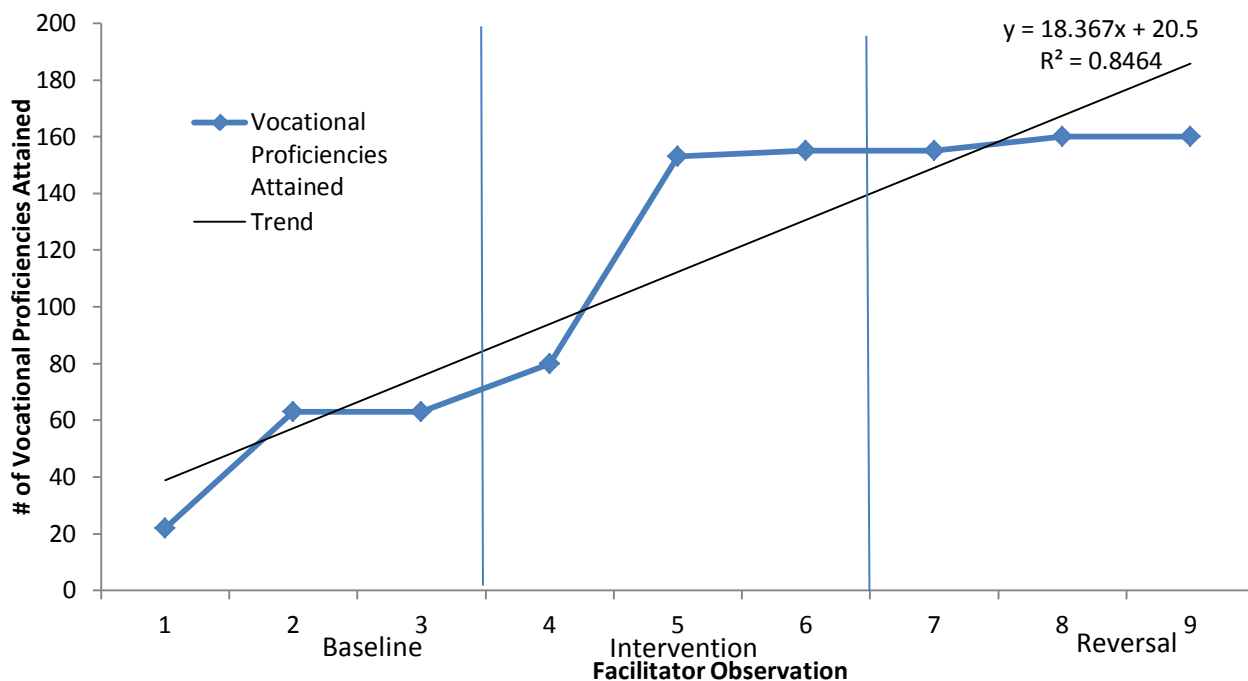
Figure 7.7. Participant 7's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TAR.)

Figure 7.7 represents the correct number of vocational proficiencies attained for each individual over the course of the baseline, treatment, and reversal phases. The number of vocational proficiencies attained should increase over time. Once a participant's evaluation indicates they have met a standard in vocational progress it will stay attained. Therefore visual analysis of levels between phases was conducted through examination of each phase's slope and mean.

Visual analysis of trend was also conducted by examining the least squares regression. The trend data, shown in Figure 7.7, indicated an upward movement through visual analysis. When calculating the least squares regression, a very strong relationship (R^2=0.85) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 7's TABE scores indicated a very small amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line.

$y = 20.5x + 8.3333$
$R^2 = 0.75$

Figure 7.8. Participant 7's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline phase.

For each individual phase the level, trend, and variability is analyzed. Figure 7.8 shows TAR data for the baseline phase. The data points of the baseline phase indicate a small variability, an upward trend, a slope of 20.5, and a trend line with a large effect (R^2=.75). This trend line indicated that participant 7's TAR scores were improving at a large rate without intervention over time.

Figure 7.9 shows TAR data for the intervention phase. The data points of the intervention phase indicated a low variability, an upward trend, a slope of 37.5, and a trend line with a large effect (R^2=.77). This trend line indicated that participant 7's TAR scores were still trending upward with intervention but at an even greater rate than the baseline phase.

Figure 7.10 shows TAR data for the reversal phase. The data for the reversal phase indicated a low variability, an upward trend, a slope of 2.5, and a trend line with a large effect (R^2=.75). This trend line indicated that participant 7's TAR scores were improving after the intervention but now at a greatly reduced rate.
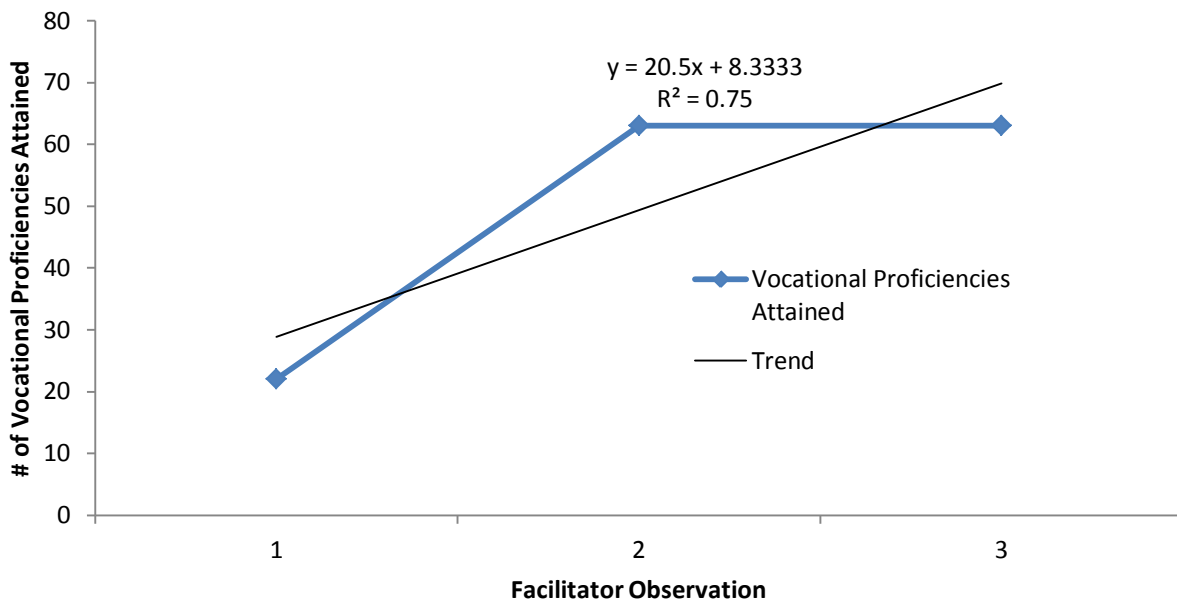

Figure 7.9. Participant 7's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the intervention phase.

162
161
160
159
158
157
156
155
154
153
152

% of Vocational Proficiencies Attained

Vocational
Proficiencies
Attained
Trend

y = 2.5x + 153.33
R² = 0.75

1   2   3

Facilitator Observation

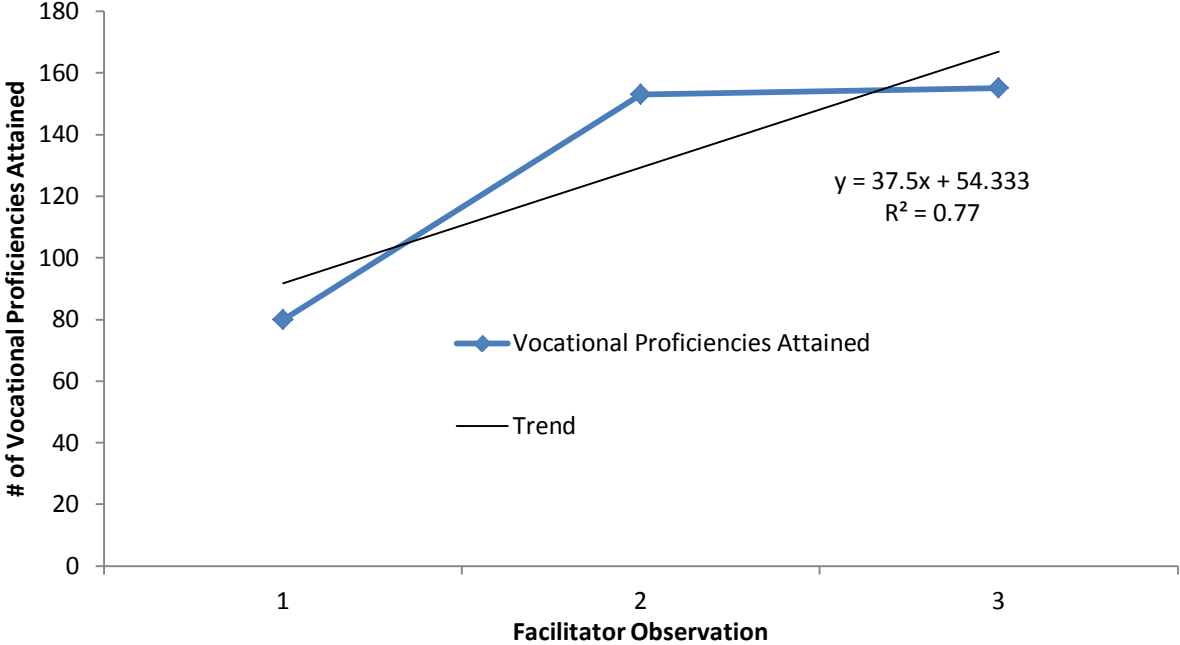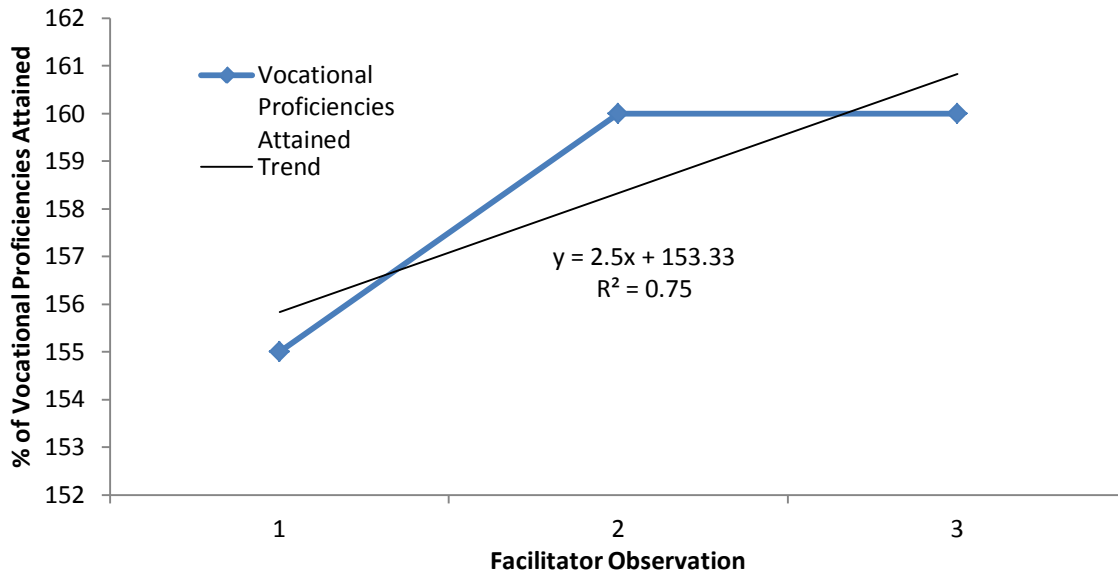*Figure 7.10.* Participant 7's number of vocational skills attained through the TAR vocational

progress monitoring evaluation during the reversal phase.

Participant 8

Participant 8was evaluated using the TABE test of numerical reasoning and reading

comprehension. Vocational progress was monitored through TAR evaluations. Participant 8

received five weeks of working memory training during the intervention phase.
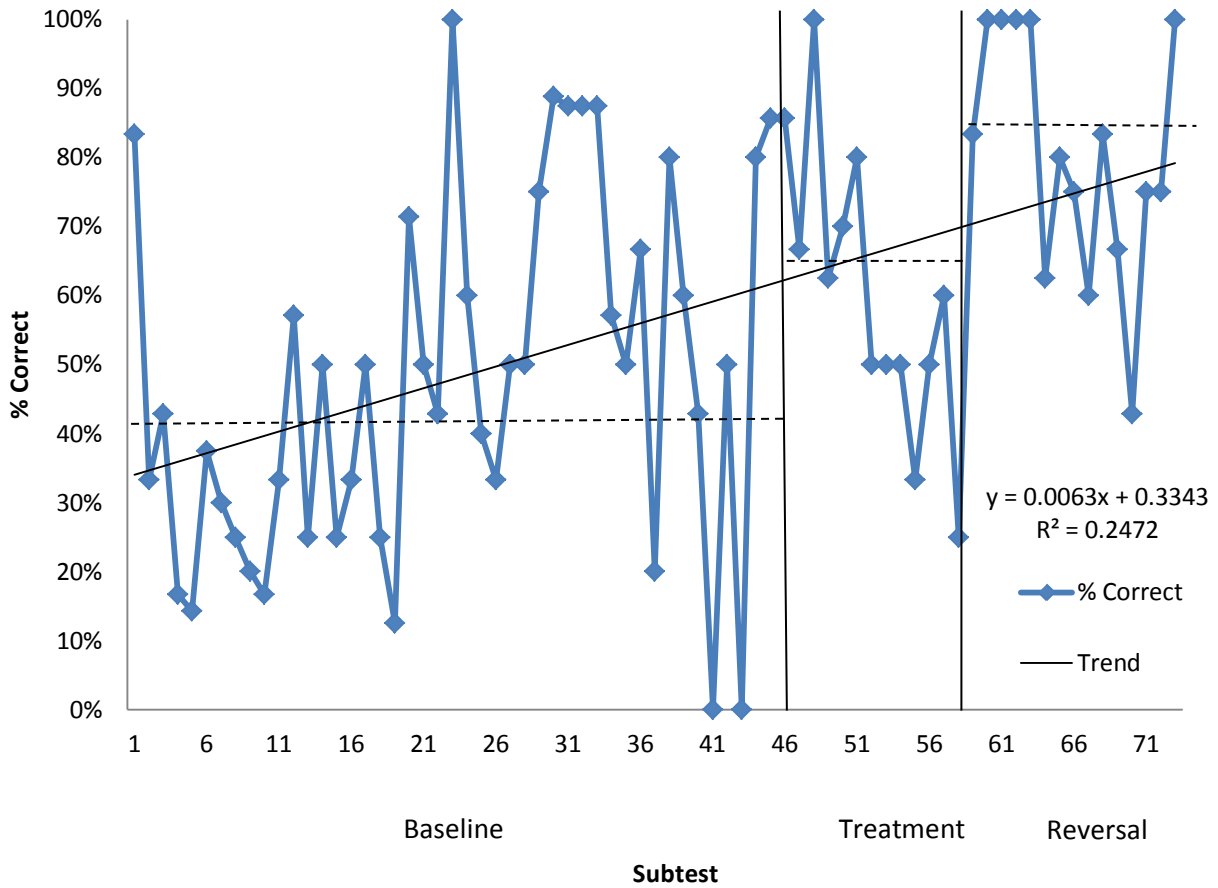
Figure 8.1. Participant 8's correctness on TABE tests of mathematics during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

Figure 8.1 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 8.1 provides a graphical representation of the observed TABE scores for participant 8 across all phases of the study. The visual analysis of levels between phases was conducted through examination of each phase's mean. As is evident from the graph, the mean of each phase (shown by the dashed black line) increased over the study. In Phase 1, the mean was 46%; in Phase 2, the mean was 63%, and in Phase 3, the mean was 80%. The increase in mean over time showed that participant 8's percentage of correctness on the TABE exam increased.

Visual analysis of trend was also conducted by examining the least squares regression. The trend is the slope and magnitude of the data that is described qualitatively. The trend data, shown in Figure 8.1, indicated an upward movement through visual analysis. When calculating the least squares regression, a large relationship (R^2=0.25) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 8's TABE mathematics scores indicated a large amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation was calculated to show the dispersion from the average. Participant 8's standard deviation for the entire experiment was 26.7%(σ=.267, σ^2=.071).
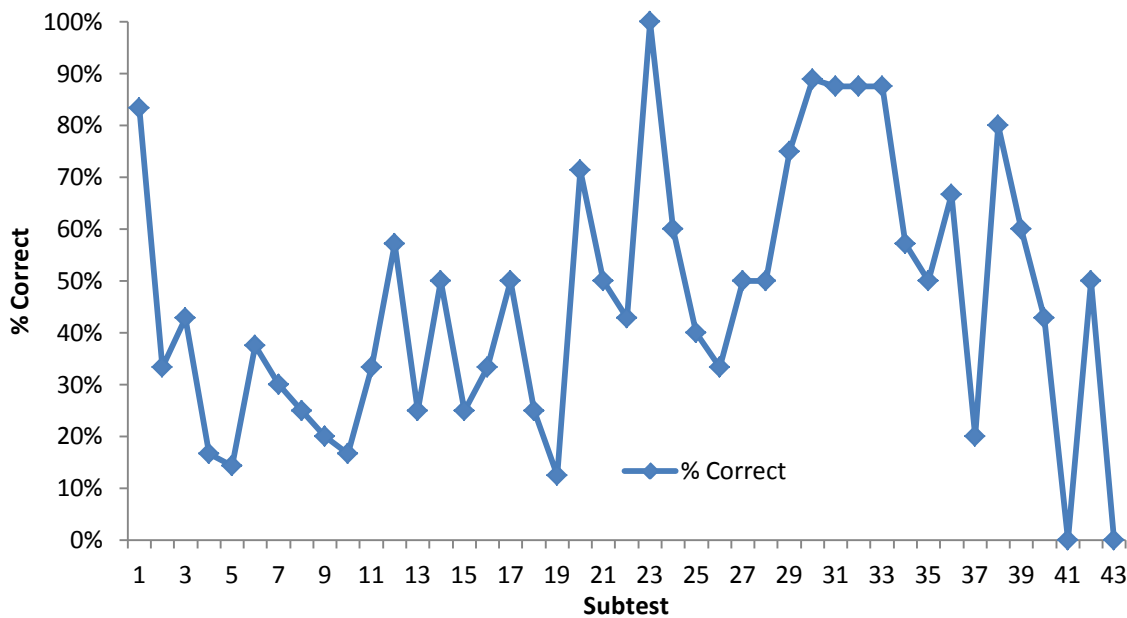
Figure 8.2. Participant 8's correctness trend for the TABE Math during the baseline phase.

For each individual phase the level and variability is analyzed. Figure 8.2 shows TABE data for the baseline phase. The data points of the baseline phase indicate a mean of 46% and a

standard deviation of 25.5%(σ=.255, σ^2=.065). Figure 8.3 shows TABE data for the

intervention phase. The data points of the intervention phase indicated a mean of 63% and a

standard deviation of 20.7%(σ=.207, σ^2=.043). Figure 8.4 shows TABE data for the reversal

phase. The data for the reversal phase indicated a mean of 80% and a standard deviation of

17.6%(σ=.176 σ^2=.031). This trend line indicated that participant 8's TABE scores were

improving after the intervention and variability of scores decreased through each phase.
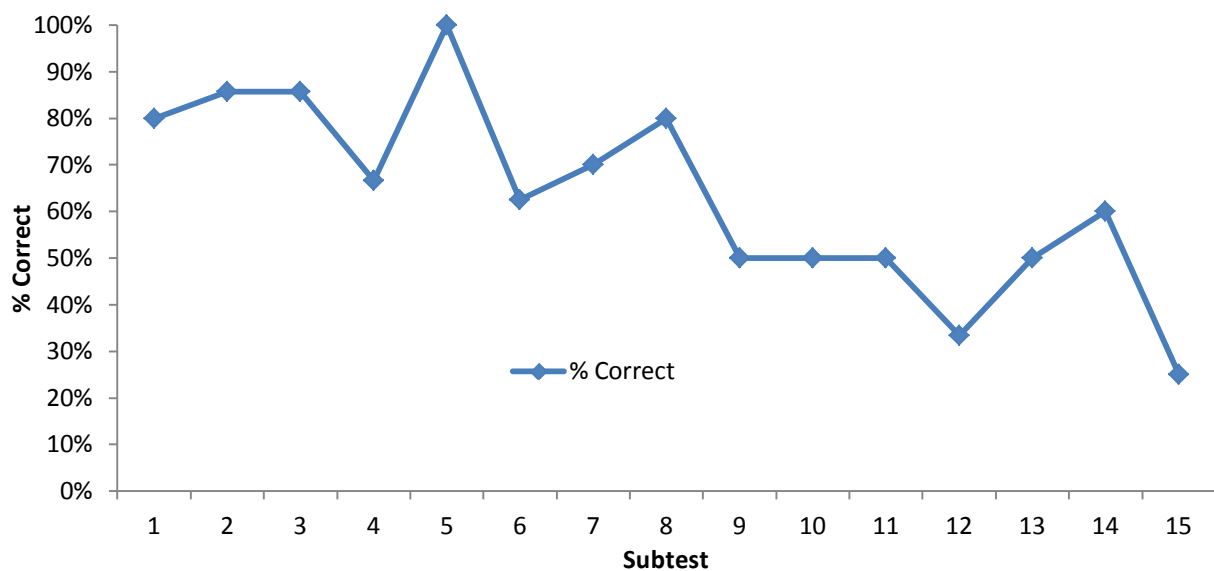
Figure 8.3. Participant 8's correctness trend for the TABE Math during the treatment phase.
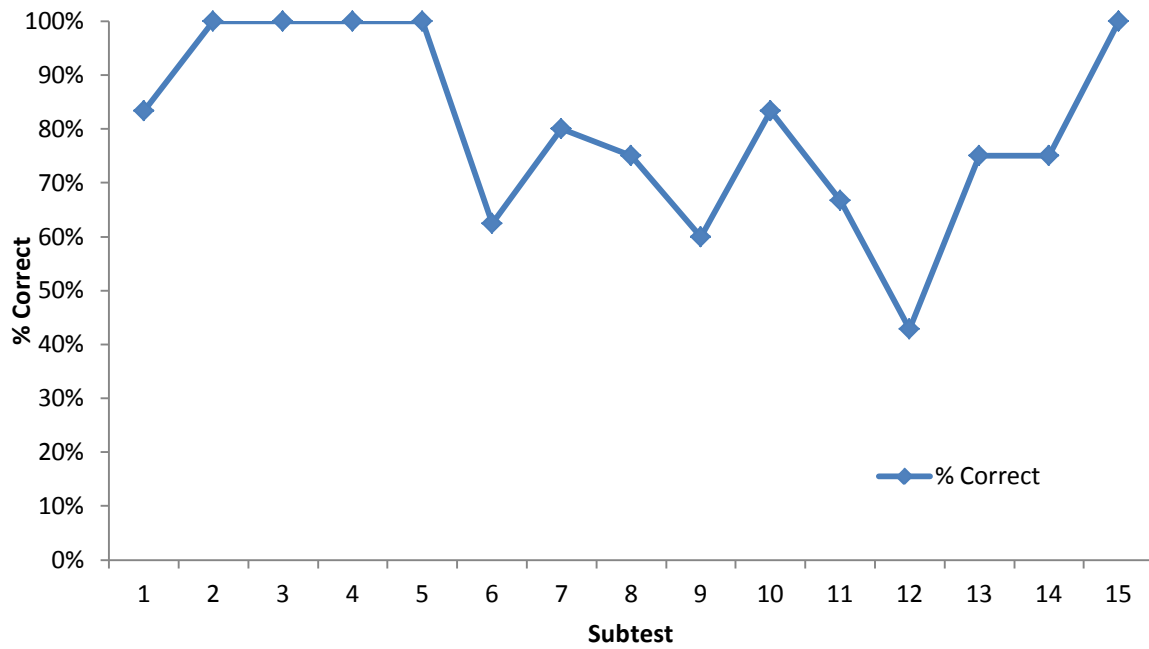
Figure 8.4. Participant 8's correctness trend for the TABE Math during the reversal phase.

$$y = 0.0154x + 0.3806$$
$$R^2 = 0.3031$$
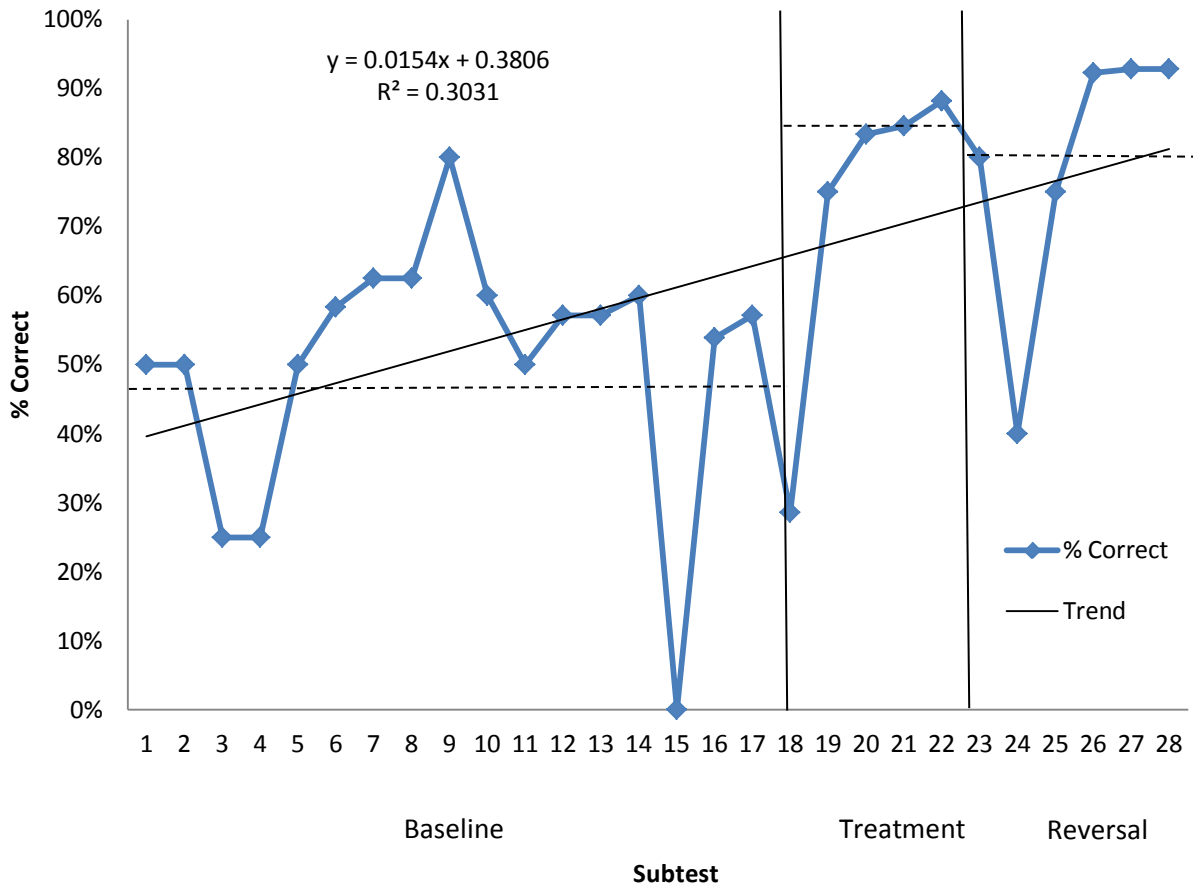
Figure 8.5. Participant 8's correctness on TABE tests of reading comprehension during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

    Figure 8.5 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 8.5 provides a graphical representation of the observed TABE scores for participant 8 across all phases of the study. The visual analysis of levels between phases was conducted through examination of each phase's mean. As is evident from the graph, the mean of each phase (shown by the dashed black line) increased over the study. In Phase 1, the mean was 49%; in Phase 2, the mean was 82%, and in Phase 3, the mean was 79%. The increase in mean over time showed that participant 8's percentage of correctness on the TABE exam increased.

Visual analysis of trend was also conducted by examining least squares regression. The trend is the slope and magnitude of the data that is described qualitatively. The trend data, shown in Figure 8.5, indicated an upward movement through visual analysis. When calculating the least squares regression, a large relationship (R^2=0.30) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 8's TABE reading scores indicated a large amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation was calculated to show the dispersion from the average. Participant 8's standard deviation for the entire experiment was 23.0%(σ=.230, σ^2=.053).
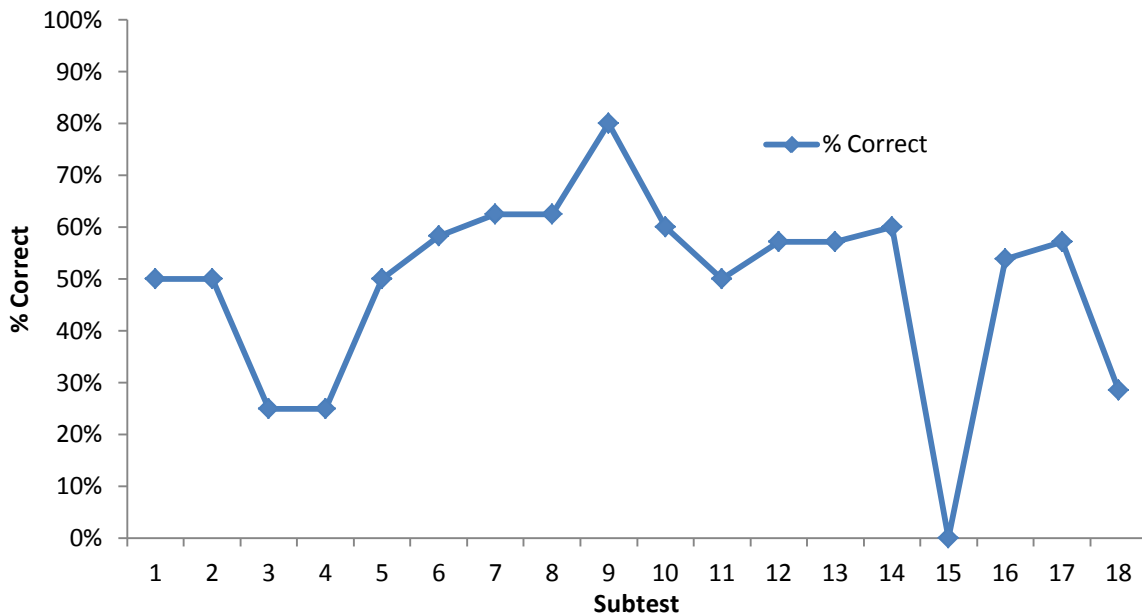
Figure 8.6. Participant 8's correctness trend for the TABE Reading during the reversal phase.

For each individual phase the level and variability was analyzed. Figure 8.6 shows TABE data for the baseline phase. The data points of the baseline phase indicate a mean of 49% and a standard deviation of 18.5%(σ=.185, σ^2=.034). Figure 8.7 shows TABE data for the

intervention phase. The data points of the intervention phase indicated a mean of 82% and a standard deviation of 5.0%(σ=.050, σ^2=.003). Figure 8.8 shows TABE data for the reversal phase. The data for the reversal phase indicated a mean of 79% and a standard deviation of 22.9%(σ=.229, σ^2=.052). This trend line indicated that participant 8's TABE scores were improving after the intervention.
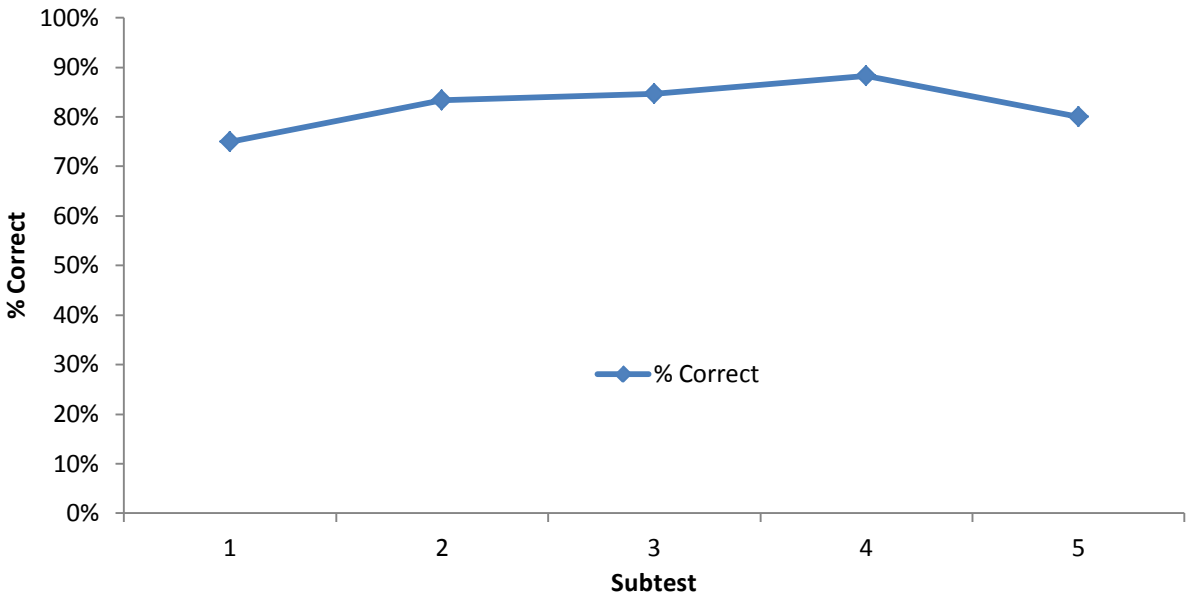
Figure 8.7. Participant 8's correctness trend for the TABE Reading during the reversal phase.
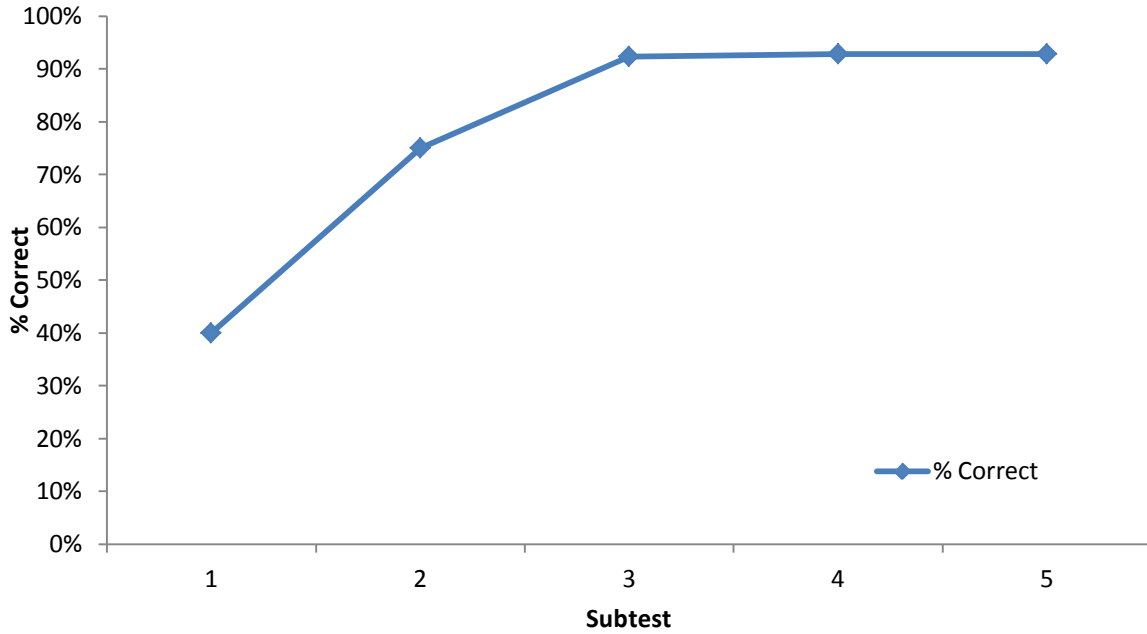
Figure 8.8. Participant 8's correctness trend for the TABE Reading during the reversal phase.
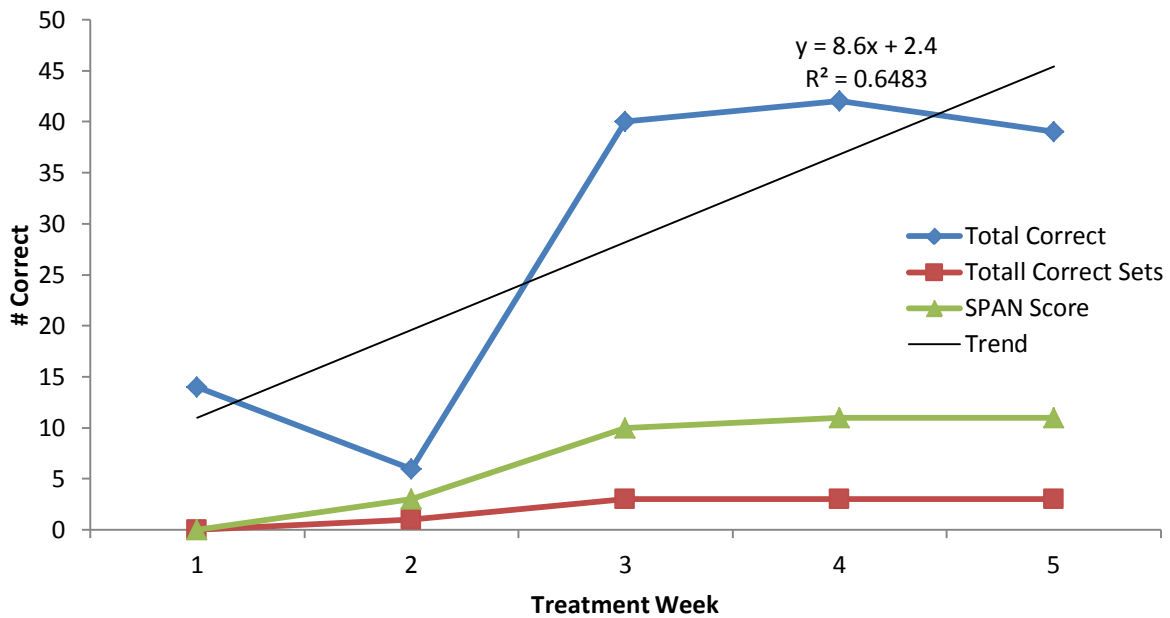
Figure 8.9. Participant 8's correctness data for the working memory treatment phase. (Increase

indicates improved performance on working memory training tasks.)

For each graph representing working memory training scores the trend and variability are analyzed. Figure 8.9 shows values of correctness and SPAN scores over the five weeks of the intervention phase. The data points of the treatment indicate a small variability, a large upward trend, and a trend line with a large effect ($R^2=.65$). This trend line indicated that participant 8's working memory training scores were greatly improving over time.

Figure 8.10 shows values of error over the five weeks of the intervention phase. The data points of the intervention phase indicated a medium variability, a large downward trend, and a trend line with a large effect ($R^2=.33$). This trend line indicated that participant 8's working memory training errors were greatly decreasing over time.
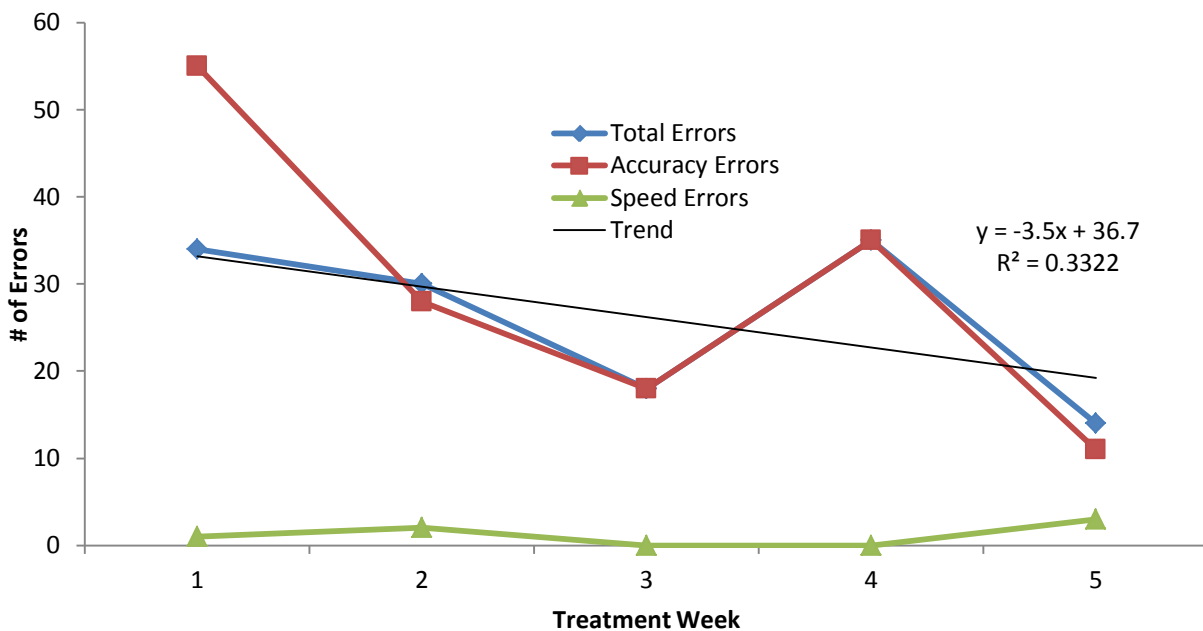
Figure 8.10. Participant 8's error data for the working memory treatment phase. (Decrease indicates improved performance on working memory training tasks.)

$$y = 12.4x - 7.8889$$
$$R^2 = 0.9589$$
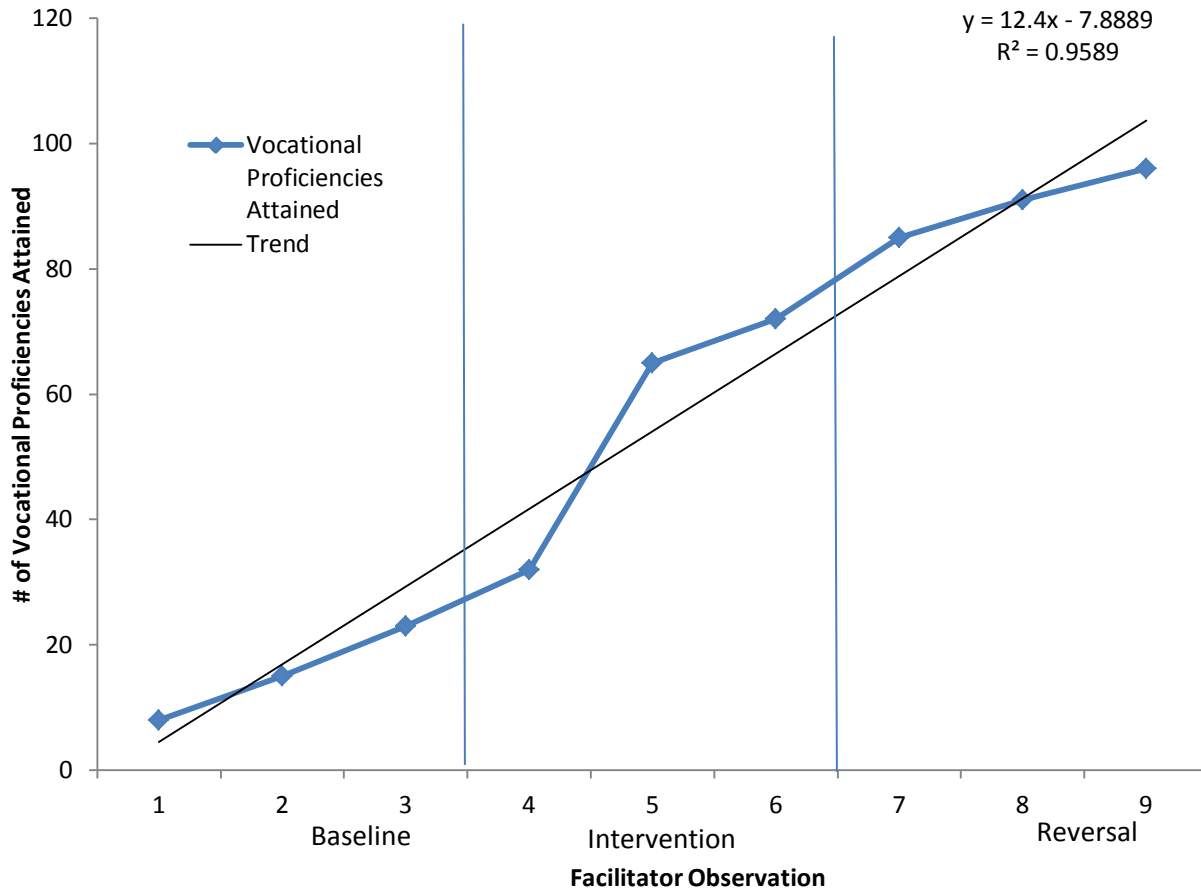
Figure 8.11. Participant 8's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TAR.)

Figure 8.11 represents the correct number of vocational proficiencies attained for each individual over the course of the baseline, treatment, and reversal phases. The number of vocational proficiencies attained should increase over time. Once a participant's evaluation indicates they have met a standard in vocational progress it will stay attained. Therefore visual analysis of levels between phases was conducted through examination of each phase's slope and mean.

Visual analysis of trend was also conducted by examining the least squares. The trend data, shown in Figure 8.11, indicated an upward movement through visual analysis. When

calculating the least squares regression, a very strong relationship (R^2=0.96) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 8's TABE scores indicated a very small amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line.

The chart shows a y-axis labeled "# of Vocational Proficiencies Attained" ranging from 0 to 25, and an x-axis labeled "Facilitator Observation" with values 1, 2, 3. Legend: Vocational Proficiencies Attained; Trend. Equation: $y = 7.5x + 0.3333$, $R^2 = 0.9985$.

Figure 8.12. Participant 8's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline phase.

For each individual phase the level, trend, and variability is analyzed. Figure 8.12 shows TAR data for the baseline phase. The data points of the baseline phase indicate a small variability, an upward trend, a slope of 7.5, and a trend line with a large effect (R^2=.99). This trend line indicated that participant 8's TAR scores were improving without intervention over time.

Figure 8.13 shows TAR data for the intervention phase. The data points of the intervention phase indicated a low variability, an upward trend, a slope of 20, and a trend line with a large effect ($R^2=.88$). This trend line indicated that participant 8's TAR scores were still trending upward with a larger slope during the intervention phase.

Figure 8.14 shows TAR data for the reversal phase. The data for the reversal phase indicated a low variability, an upward trend, a slope of 5.5, and a trend line with a large effect ($R^2=.99$). This trend line indicated that participant 8's TAR scores were not improving as the same rate after the intervention compared to during the intervention.
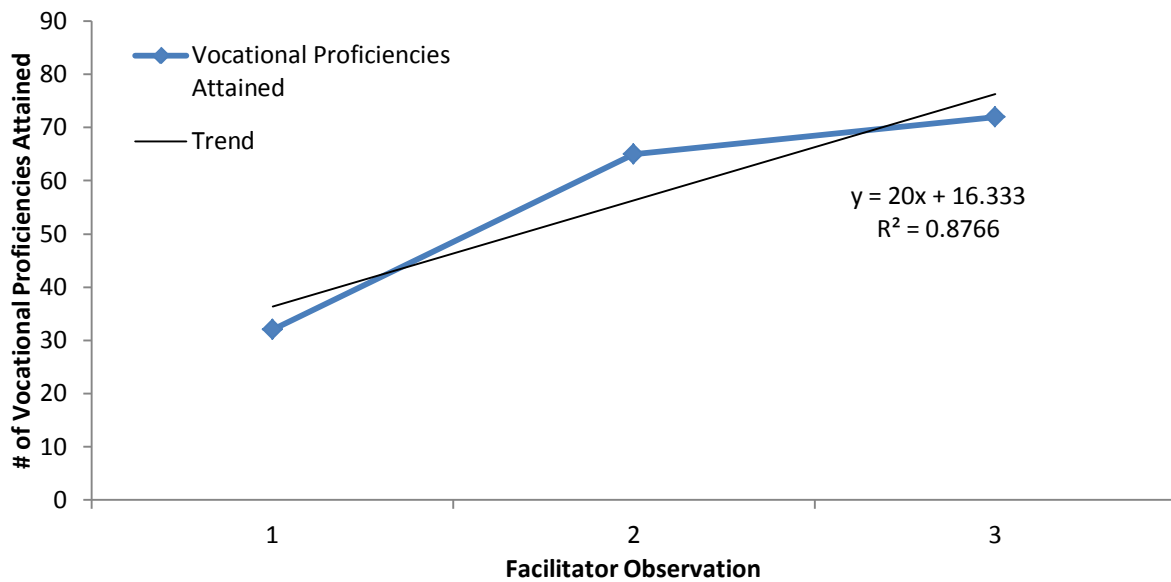
Figure 8.13. Participant 8's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the intervention phase.

The chart shows:
- Y-axis: **% of Vocational Proficiencies Attained** ranging from 78 to 98
- X-axis: **Facilitator Observation** with values 1, 2, 3
- Legend: Vocational Proficiencies Attained, Trend
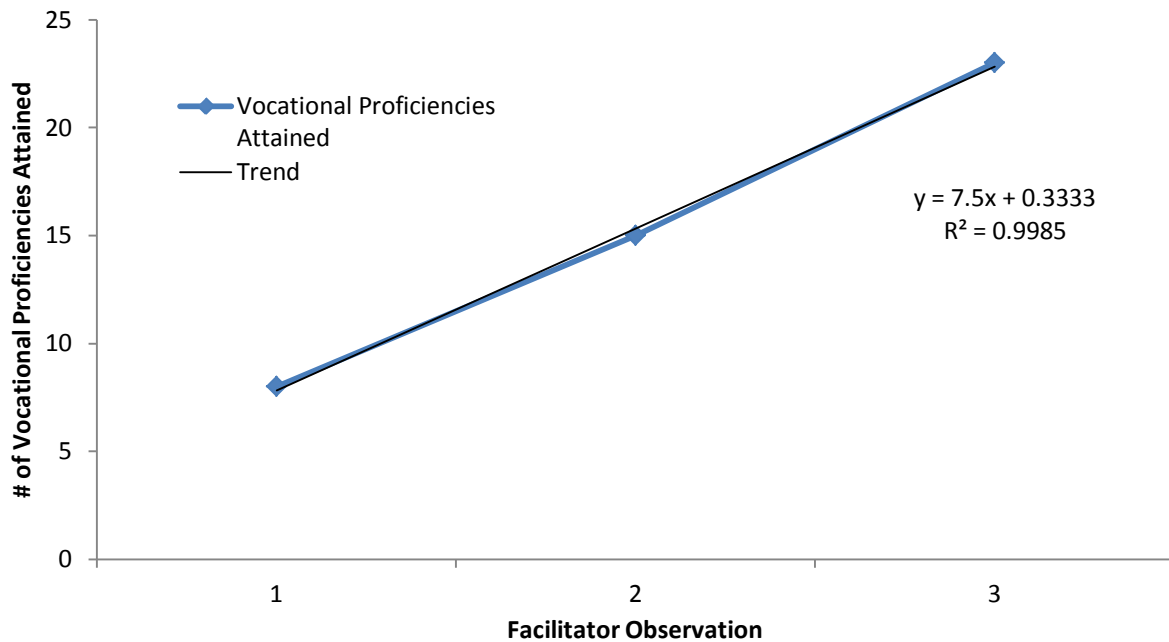
$$y = 5.5x + 79.667$$
$$R^2 = 0.9973$$
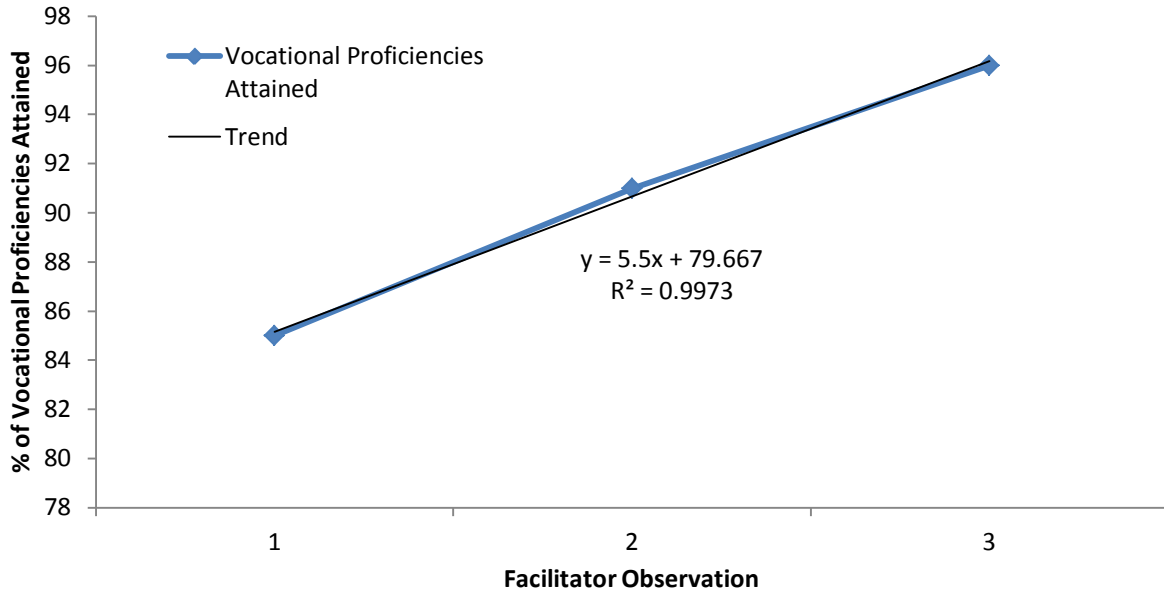
Figure 8.14. Participant 8's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the reversal phase.

Participant 9

Participant 9was evaluated using the TABE test of reading comprehension and observed using TAR vocational progress monitoring survey. Participant 9 received five weeks of working memory training during the intervention phase.
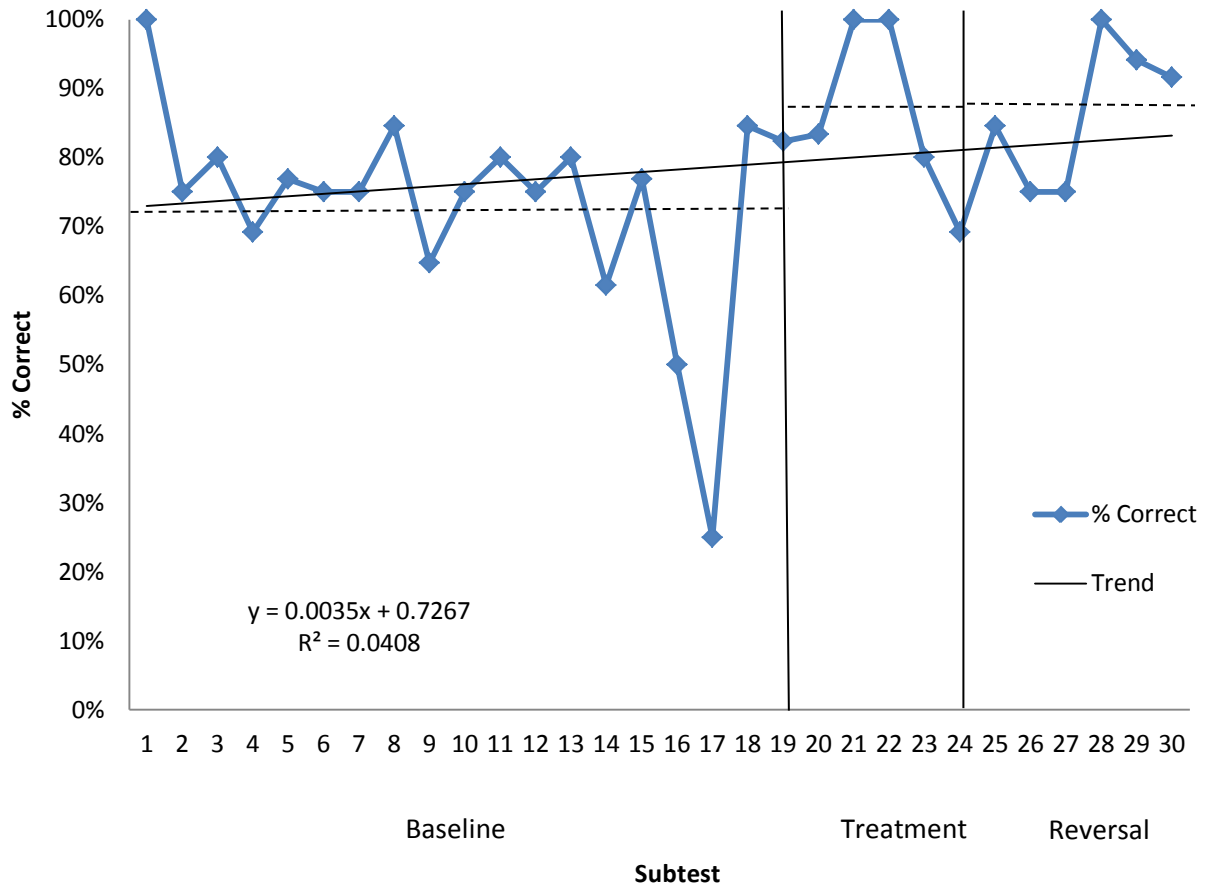
Figure 9.1. Participant 9's correctness on TABE tests of mathematics during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

Figure 9.1 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 9.1 provides a graphical representation of the observed TABE scores for participant 9 across all phases of the study. The visual analysis of levels between phases was conducted through examination of each phase's mean. As is evident from the graph, the mean of each phase (shown by the dashed black line) increased over the study. In Phase 1, the mean was 74%; in Phase 2, the mean was 87%, and in Phase 3, the mean was 87%. The increase in mean over time showed that participant 9's percentage of correctness on the TABE exam increased.

Visual analysis of trend was also conducted by examining the least squares regression. The trend is the slope and magnitude of the data that is described qualitatively. The trend data, shown in Figure 9.1, indicated an upward movement through visual analysis. When calculating the least squares regression, a small relationship (R^2=.04) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 9's TABE scores indicated a moderate amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation was calculated to show the dispersion from the average. Participant 9's standard deviation for the entire experiment was 15.4%(σ=.154, σ^2=.024).
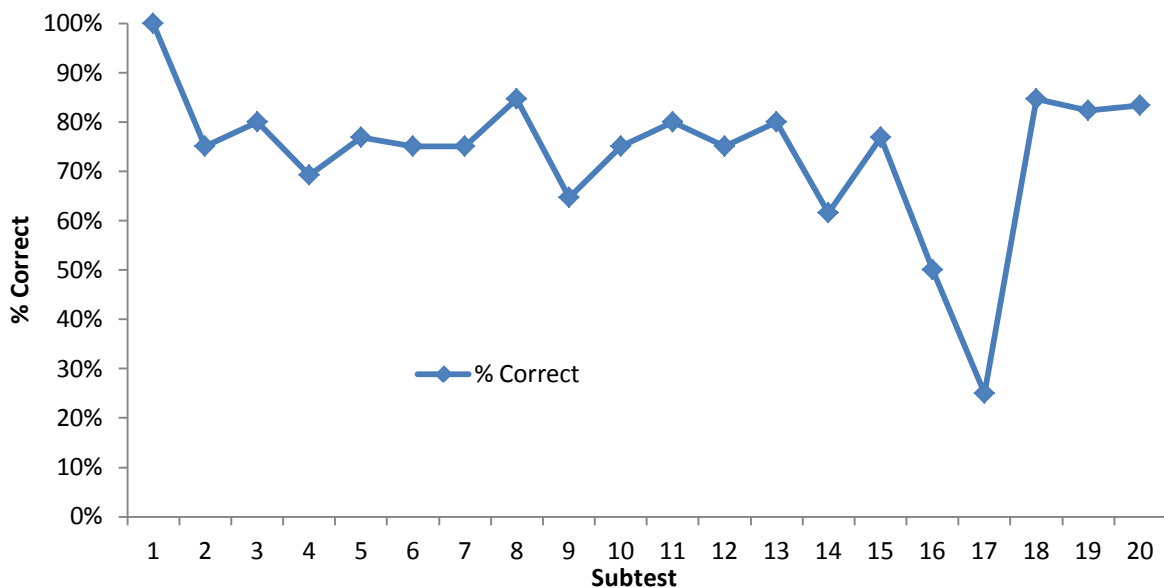
Figure 9.2. Participant 9's correctness trend for the TABE during the baseline phase.

For each individual phase the level and variability was analyzed. Figure 9.2 shows TABE data for the baseline phase. The data points of the baseline phase indicate a moderate mean of 74% and a standard deviation of 15.2%(σ=.152, σ^2=.023). Figure 9.3 shows TABE data for the intervention phase. The data points of the intervention phase indicated a mean of

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87% and a standard deviation of 13.3%(σ=.133, σ^2=.018). Figure 9.4 shows TABE data for the reversal phase. The data for the reversal phase indicated a mean of 87% and a standard deviation of 11.5%(σ=.115, σ^2=.013). This trend line indicated that participant 9's TABE scores were improved after the intervention phase and decreased in variability through each phase.
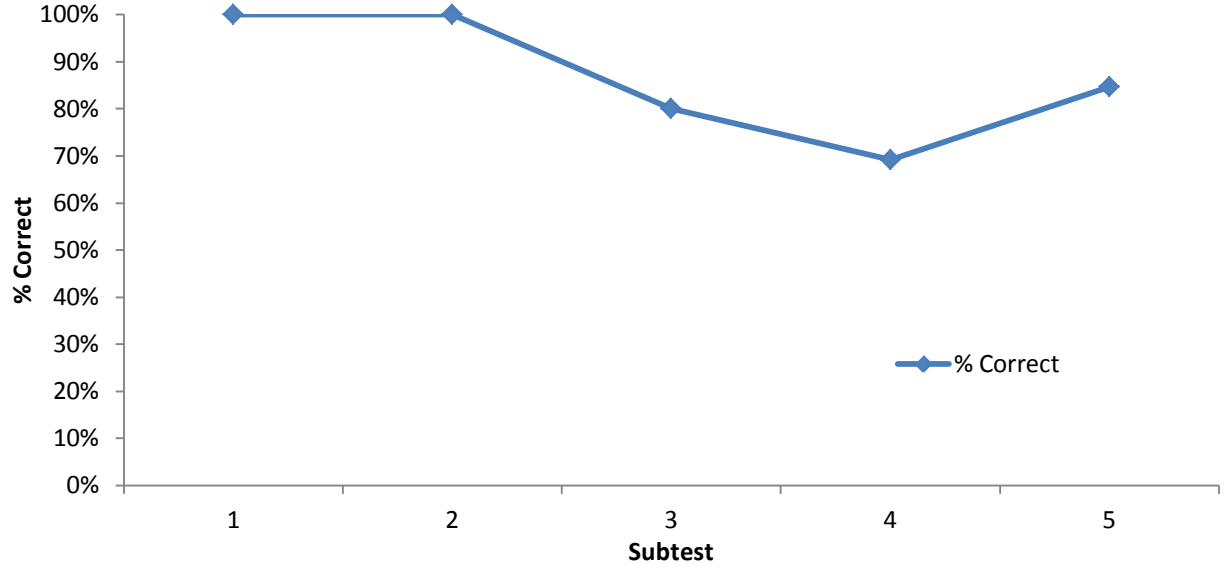
Figure 9.3. Participant 9's correctness trend for the TABE during the treatment phase.
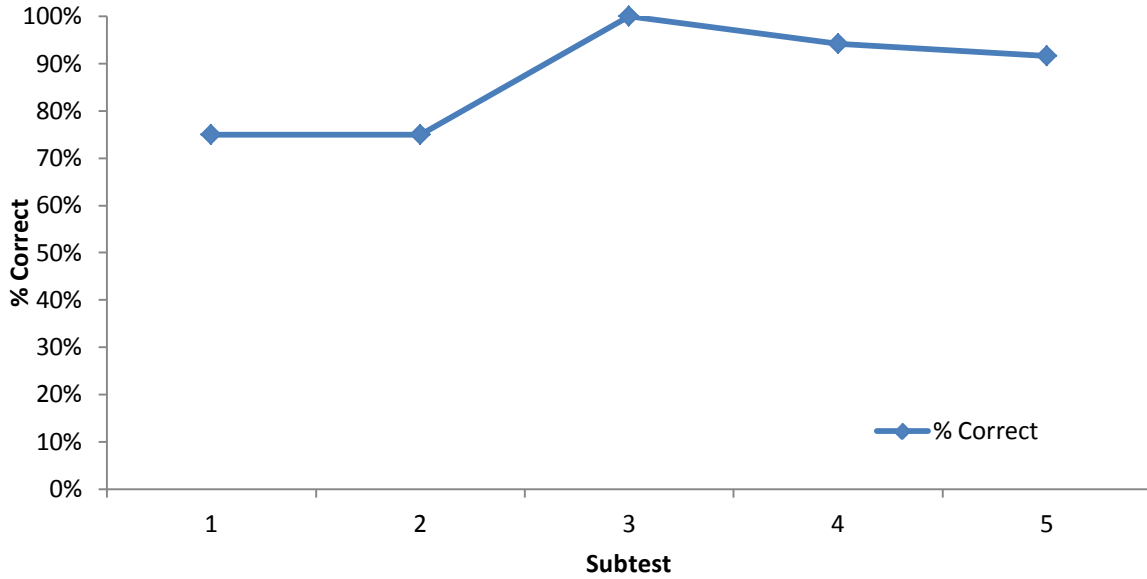
Figure 9.4. Participant 9's correctness trend for the TABE during the reversal phase.
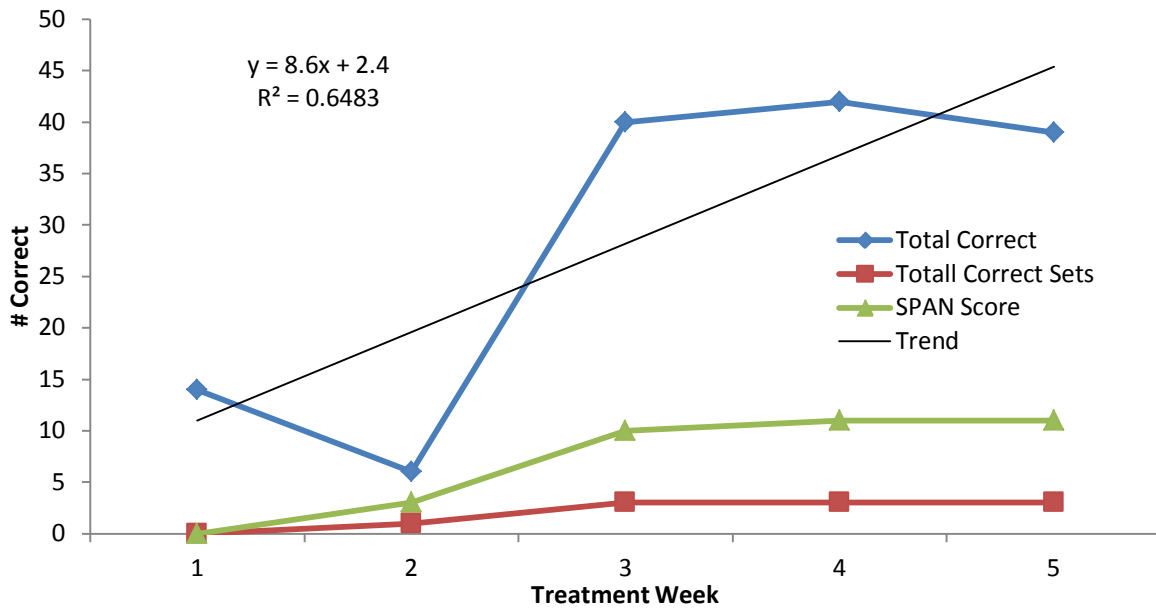
Figure 9.5. Participant 9's correctness data for the working memory treatment phase. (Increase

indicates improved performance on working memory training tasks.)

For each graph representing working memory training scores the trend and variability are

analyzed. Figure 9.5 shows values of correctness and SPAN scores over the five weeks of the

intervention phase. The data points of the treatment indicate a low to medium variability, a large

upward trend, and a trend line with a large effect (R^2=.65). This trend line indicated that participant 9's working memory training scores were greatly improving over time.

Figure 9.6 shows values of error over the five weeks of the intervention phase. The data points of the intervention phase indicated a medium variability, a downward trend, and a trend line with a large effect (R^2=.33). This trend line indicated that participant 9's working memory training errors were decreasing over time.
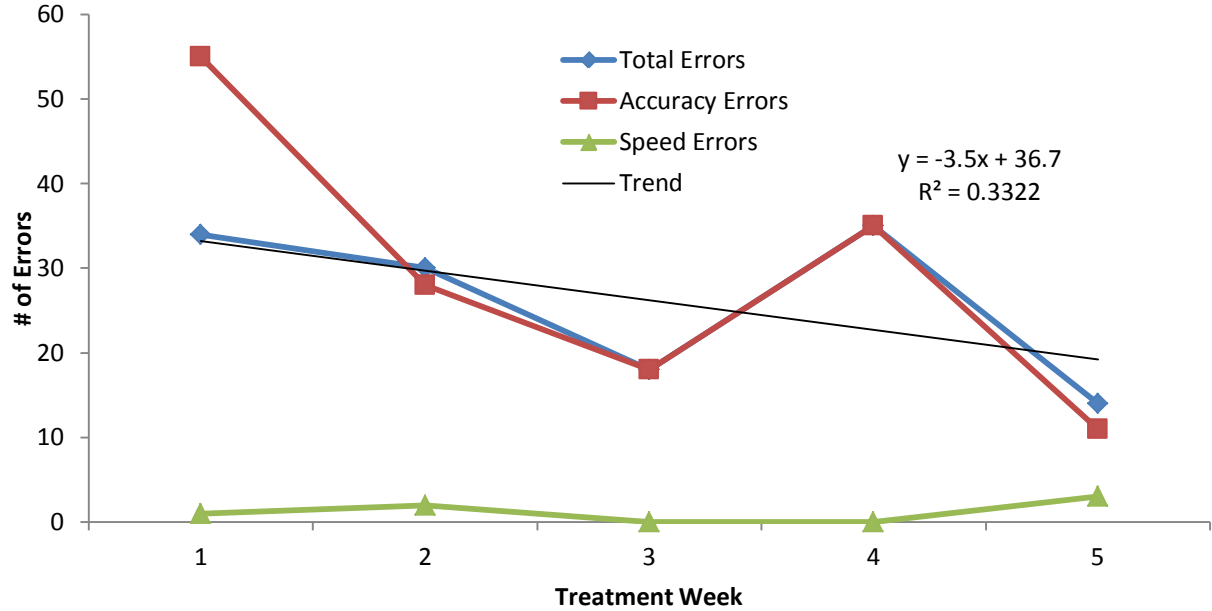
Figure 9.6. Participant 9's error data for the working memory treatment phase. (Decrease indicates improved performance on working memory training tasks.)

Figure 9.7. Participant 9's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TAR.)

Figure 9.7 represents the correct number of vocational proficiencies attained for each individual over the course of the baseline, treatment, and reversal phases. The number of vocational proficiencies attained should increase over time. Once a participant's evaluation indicates they have met a standard in vocational progress it will stay attained. Therefore visual analysis of levels between phases was conducted through examination of each phase's slope and mean.

Visual analysis of trend was also conducted by examining the least squares. The trend data, shown in Figure 9.7, indicated an upward movement through visual analysis. When

calculating the least squares regression, a very strong relationship (R^2=0.96) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 9's TABE scores indicated a very small amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line.

Figure 9.8 chart: X-axis labeled "Facilitator Observation" (values 1, 2, 3), Y-axis labeled "# of Vocational Proficiencies Attained" (0 to 25). Legend shows "Vocational Proficiencies Attained" and "Trend". Equation shown: y = 7.5x + 0.3333, R^2 = 0.9985.

Figure 9.8. Participant 9's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline phase.

For each individual phase the level, trend, and variability is analyzed. Figure 9.8 shows TAR data for the baseline phase. The data points of the baseline phase indicate a small variability, an upward trend, a slope of 7.5, and a trend line with a large effect (R^2=.99). This trend line indicated that participant 9's TAR scores were improving without intervention over time.

Figure 9.9 shows TAR data for the intervention phase. The data points of the intervention phase indicated a low variability, an upward trend, a slope of 20, and a trend line with a large

effect (R^2=.88). This trend line indicated that participant 9's TAR scores increased with a much greater rate during the intervention phase.

Figure 9.10 shows TAR data for the reversal phase. The data for the reversal phase indicated a low variability, an upward trend, a slope of 5.5, and a trend line with a large effect (R^2=.99). This trend line indicated that participant 9's TAR scores decreased the rate of increase after the intervention phase was over.
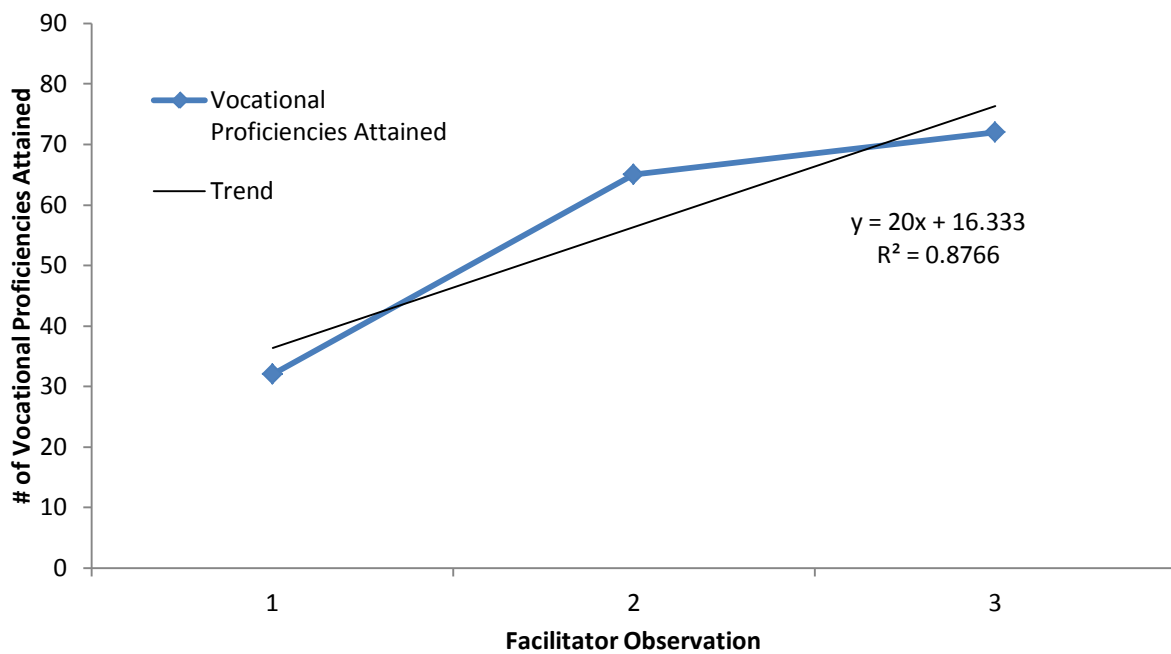
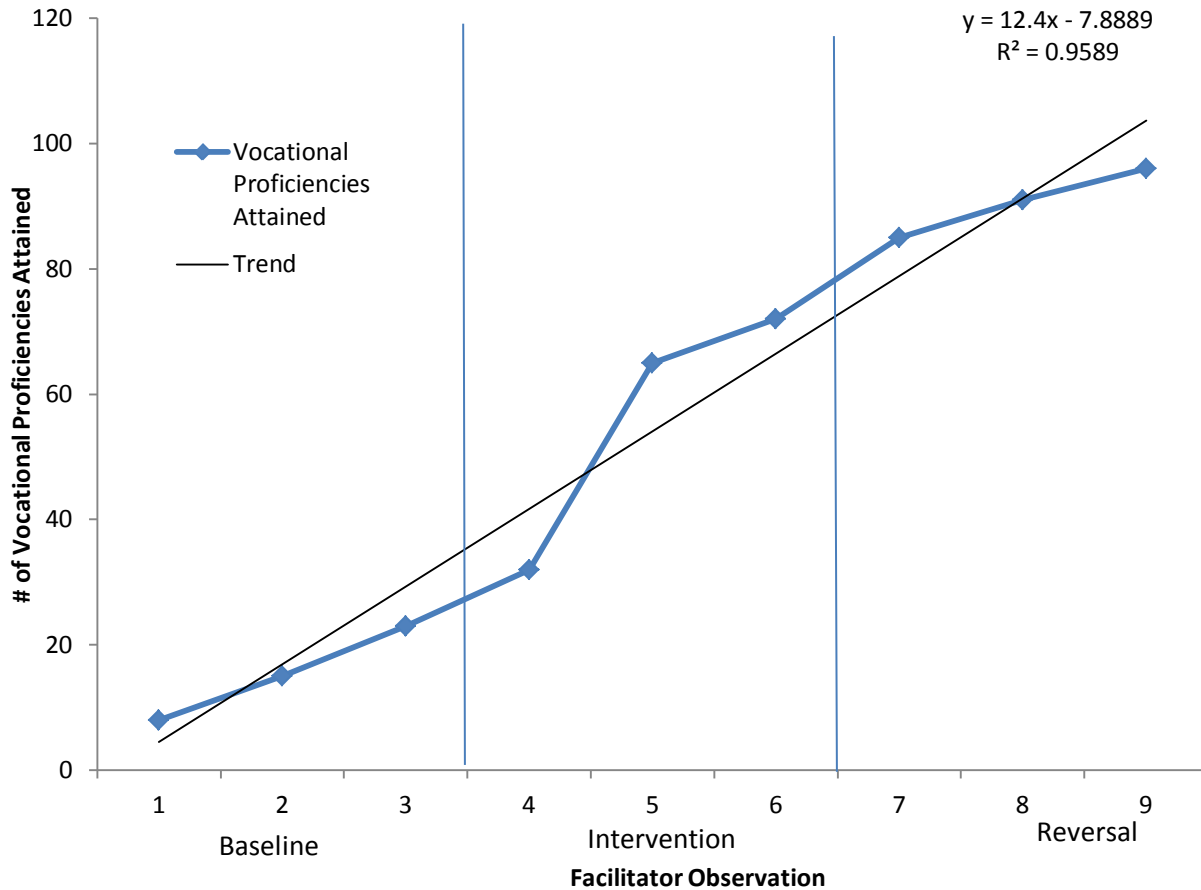*Figure 9.9.* Participant 9's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the intervention phase.

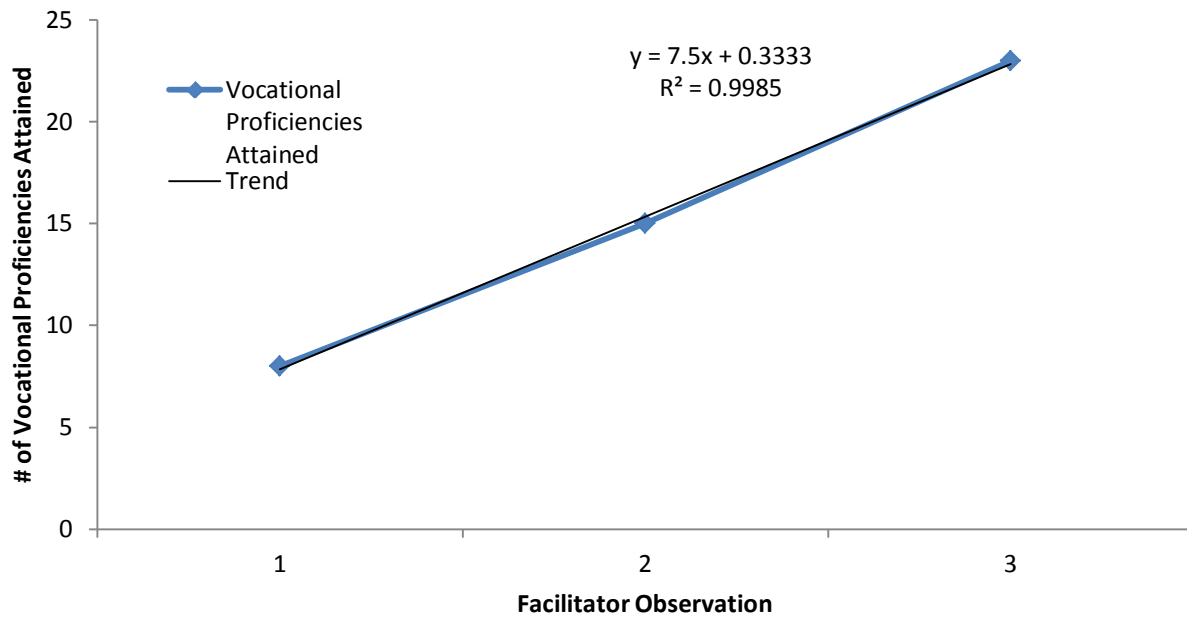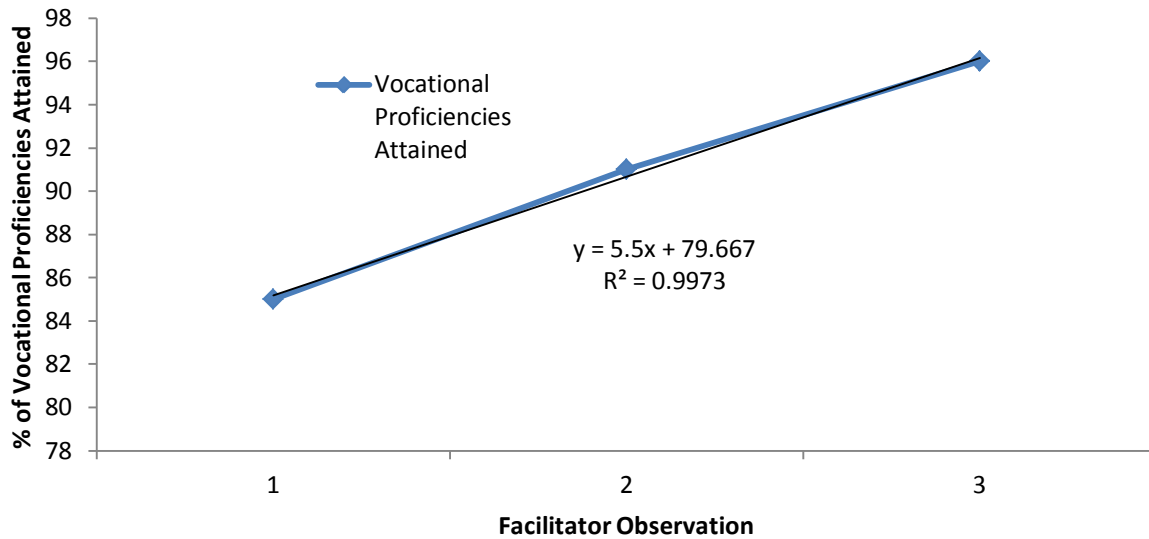*Figure 9.10.* Participant 9's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the reversal phase.

Participant 10

Participant 10 was evaluated using the TABE test of numerical reasoning and reading comprehension. Vocational progress was monitored using TAR evaluations. Participant 10 received five weeks of working memory training during the intervention phase.

Figure 10.1. Participant 10's correctness on TABE tests of mathematics during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

Figure 10.1 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 10.1 provides a graphical representation of the observed TABE scores for participant 10 across all phases of the study. The visual analysis of levels between phases was conducted through examination of each phase's mean. As is evident from the graph, the mean of each phase (shown by the dashed black line) increased over the study. In Phase 1, the mean was 54%; in Phase 2, the mean was 76%, and in Phase 3, the mean was 81%. The increase in mean over time showed that participant 10's percentage of correctness on the TABE exam increased.

Visual analysis of trend was also conducted by examining the least squares regression. The trend is the slope and magnitude of the data that is described qualitatively. The trend data, shown in Figure 10.1, indicated an upward movement through visual analysis. When calculating the least squares regression, a large relationship ($R^2=.25$) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 10's TABE mathematics scores indicated a large amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation was calculated to show the dispersion from the average. Participant 10's standard deviation for the entire experiment was 26.5%($\sigma=.265$, $\sigma^2=.070$).

Figure 10.2. Participant 10's correctness trend for the TABE during the baseline phase.

For each individual phase the level and variability is analyzed. Figure 10.2 shows TABE data for the baseline phase. The data points of the baseline phase indicate a mean of 54% and a standard deviation of 28.2%($\sigma=.282$, $\sigma^2=.080$). Figure 10.3 shows TABE data for the

intervention phase. The data points of the intervention phase indicated a mean of 76% and a standard deviation of 15.1%(σ=.151, σ^2=.023). Figure 10.4 shows TABE data for the reversal phase. The data for the reversal phase indicated a mean of 81% and a standard deviation of 20.5%(σ=.205, σ^2=.042). This trend line indicated that participant 10's TABE scores were improved from baseline and intervention but were still variable at the reversal phase.

Figure 10.3. Participant 10's correctness trend for the TABE during the treatment phase.
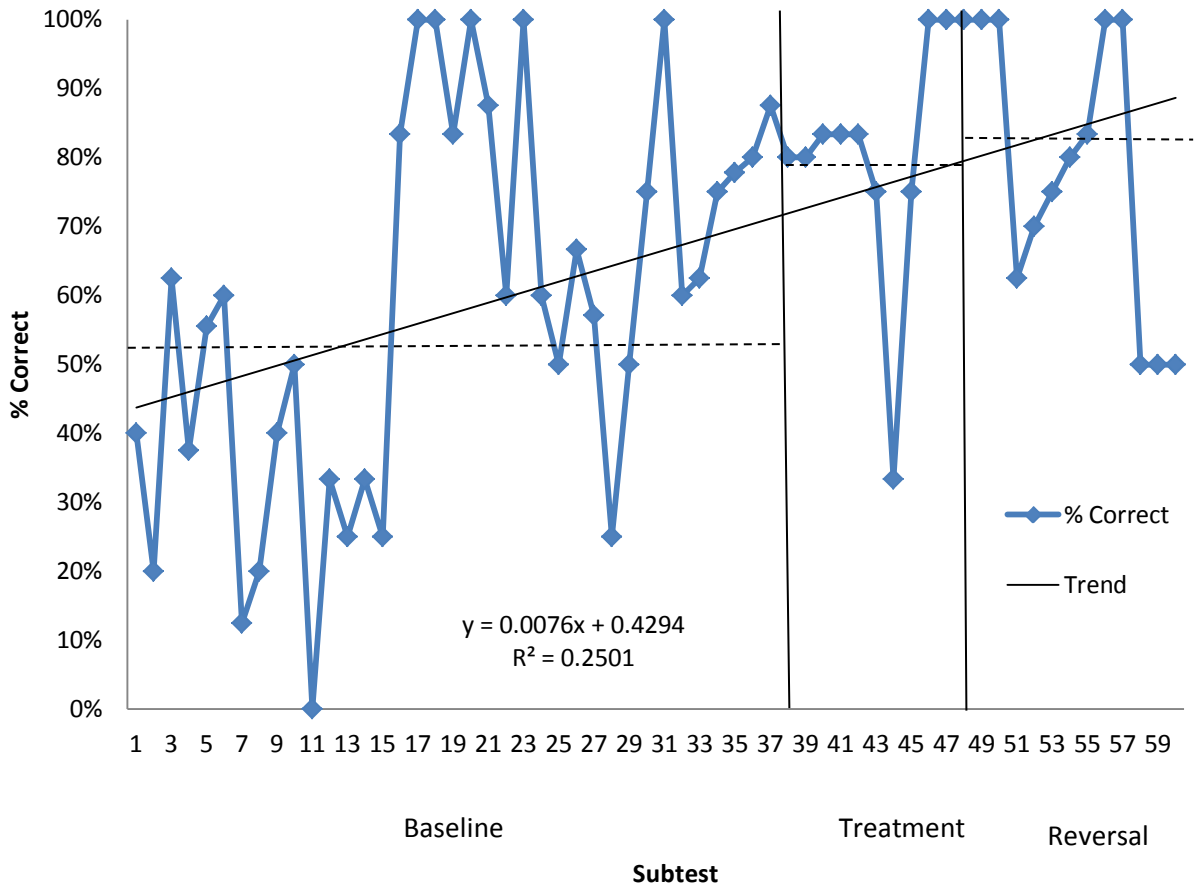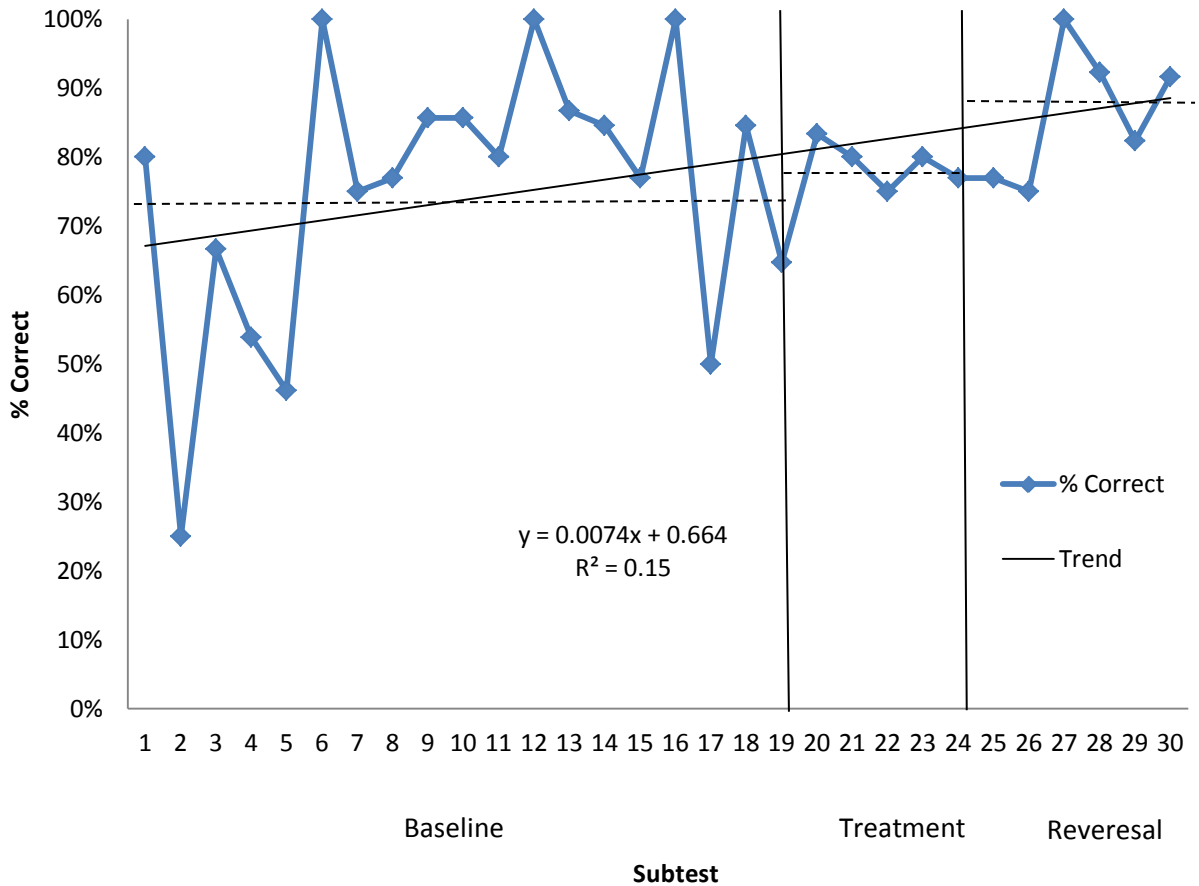
Figure 10.5. Participant 10's correctness on TABE tests of reading comprehension during the

baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

Figure 10.5 represents the correct number of problems solved for each individual TABE

measurement during the baseline, treatment, and reversal phases. Figure 10.5 provides a

graphical representation of the observed TABE scores for participant 10 across all phases of the

study. The visual analysis of levels between phases was conducted through examination of each

phase's mean. As is evident from the graph, the mean of each phase (shown by the dashed black

line) increased over the study. In Phase 1, the mean was 75%; in Phase 2, the mean was 78%, and

in Phase 3, the mean was 88%. The increase in mean over time showed that participant 10's

percentage of correctness on the TABE exam increased.

Visual analysis of trend was also conducted by examining the least squares regression. The trend is the slope and magnitude of the data that is described qualitatively. The trend data, shown in Figure 10.1, indicated an upward movement through visual analysis. When calculating the least squares regression, a medium relationship (R^2=.15) between the phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 10's TABE reading scores indicated a moderate amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation was calculated to show the dispersion from the average. Participant 10's standard deviation for the entire experiment was 16.8%(σ=.168, σ^2=.028).
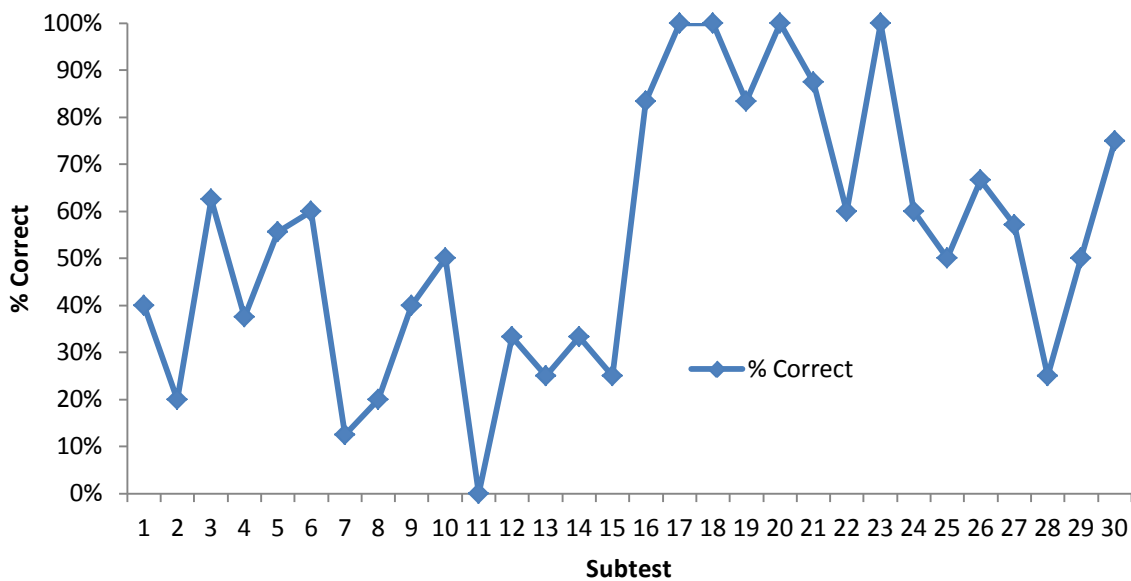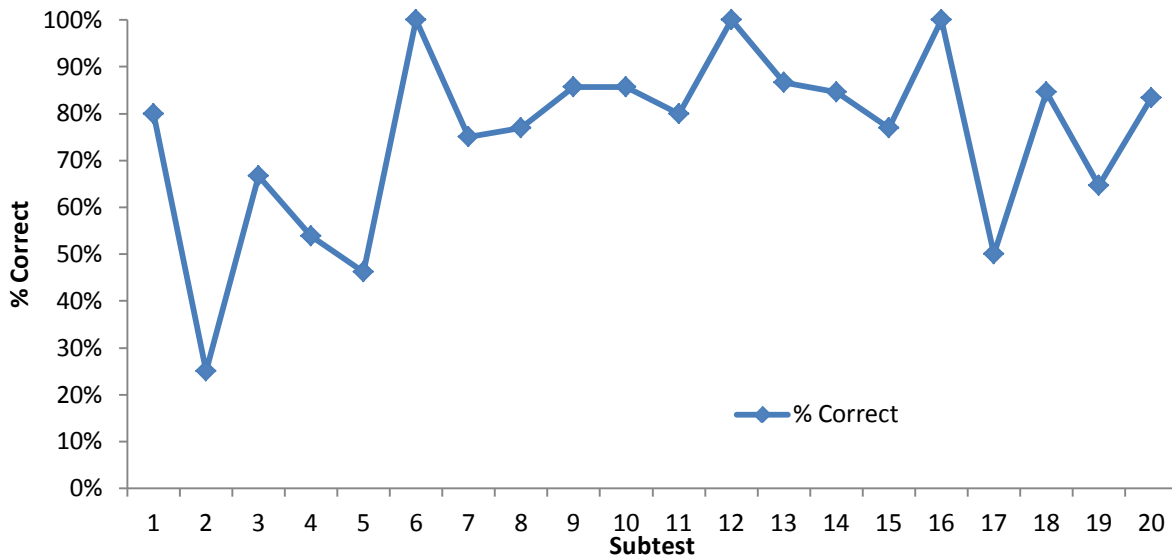

Figure 10.6. Participant 10's correctness trend for the TABE Reading during the baseline phase.

For each individual phase the level and variability is analyzed. Figure 10.6 shows TABE data for the baseline phase. The data points of the baseline phase indicate a mean of 75% and a standard deviation of 19.3%(σ=.193, σ^2=.037). Figure 10.7 shows TABE data for the

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intervention phase. The data points of the intervention phase indicated a mean of 78% and a standard deviation of 2.3%($\sigma=.023$, $\sigma^2=.001$). Figure 10.8 shows TABE data for the reversal phase. The data for the reversal phase indicated a mean of 88% and a standard deviation of 9.7%($\sigma=.097$, $\sigma^2=.009$). This trend line indicated that participant 10's TABE scores were improved from baseline and intervention and variability of scores decreased.
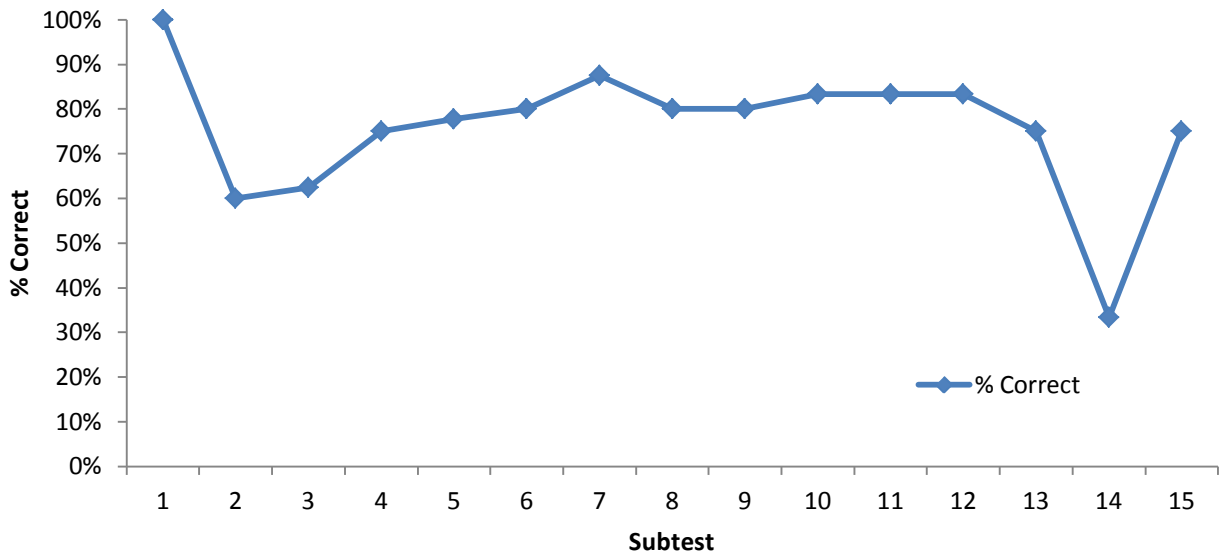

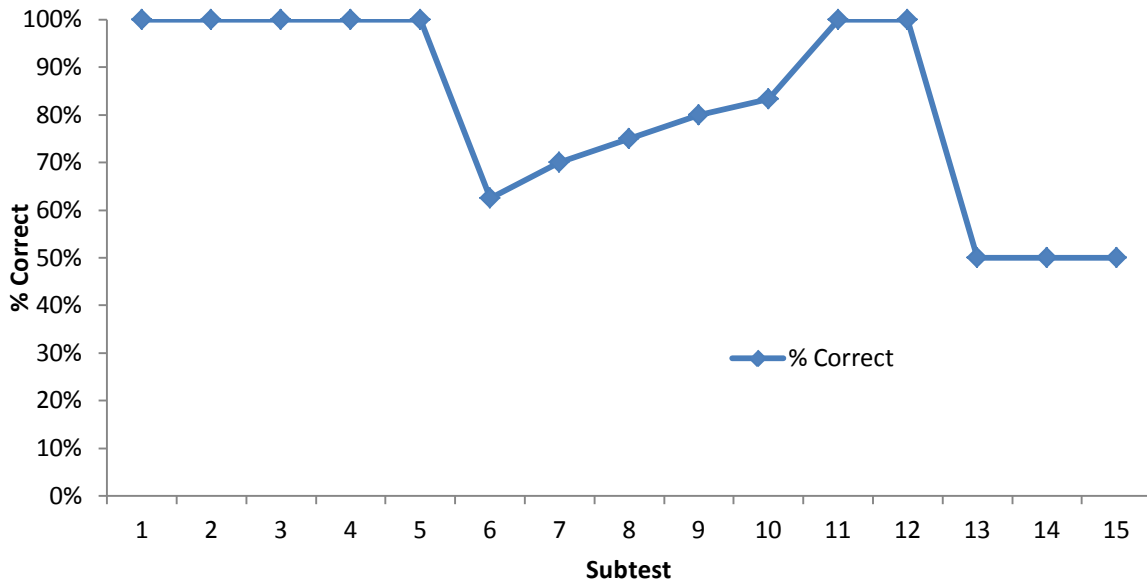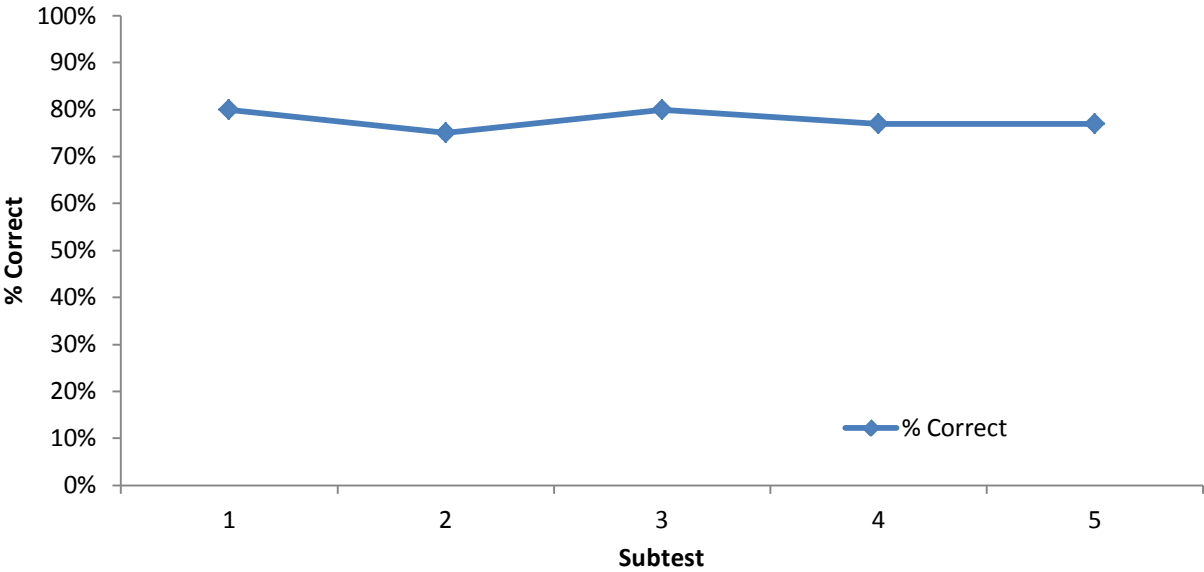*Figure 10.7*. Participant 10's correctness trend for the TABE Reading during the intervention phase.
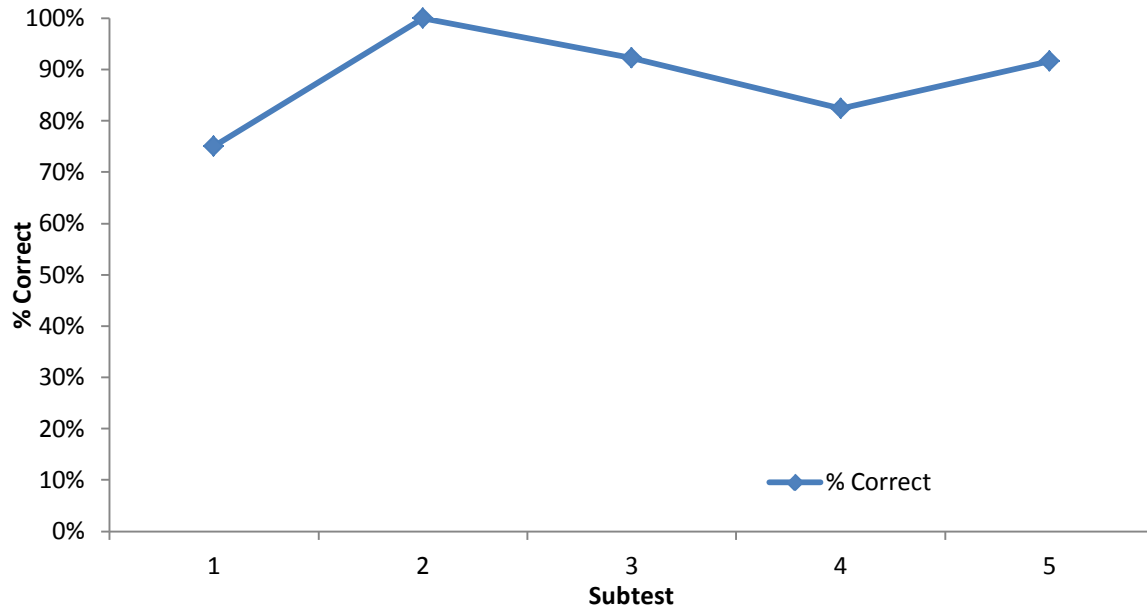
Figure 10.8. Participant 10's correctness trend for the TABE Reading during the reversal phase.
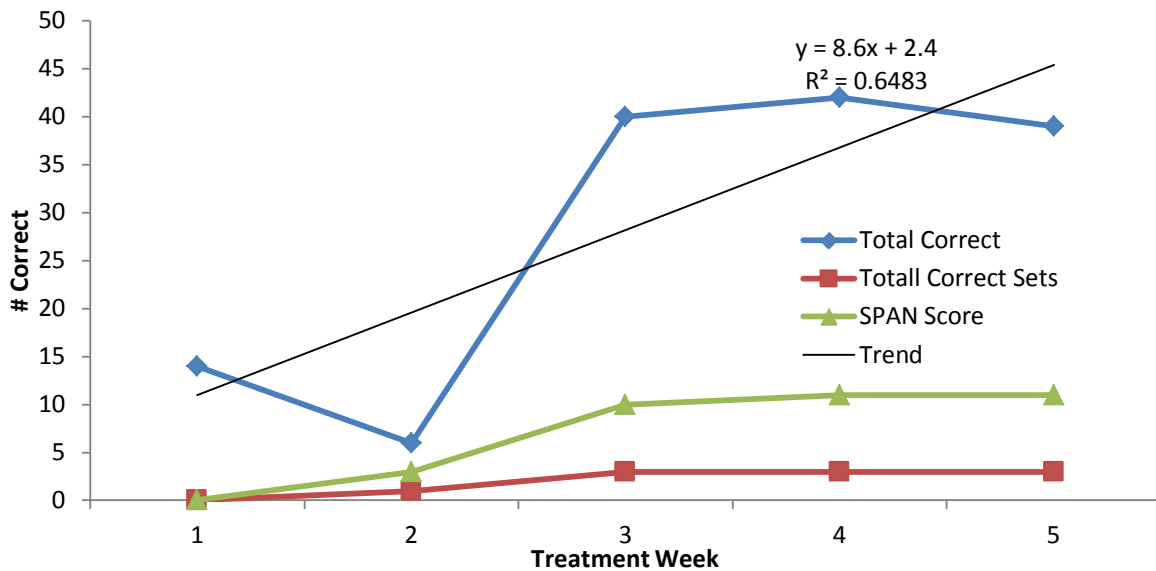
Figure 10.9. Participant 10's correctness data for the working memory treatment phase.

(Increase indicates improved performance on working memory training tasks.)

For each graph representing working memory training scores the trend and variability are analyzed. Figure10.9 shows values of correctness and SPAN scores over the five weeks of the intervention phase. The data points of the treatment indicate a small to medium variability, a large upward trend, and a trend line with a large effect (R^2=.64). This trend line indicated that participant 10's working memory training scores were greatly improving over time.

Figure 10.10 shows values of error over the five weeks of the intervention phase. The data points of the intervention phase indicated a medium variability, a large downward trend, and a trend line with a large effect (R^2=.33). This trend line indicated that participant 10's working memory training errors were greatly decreasing over time.
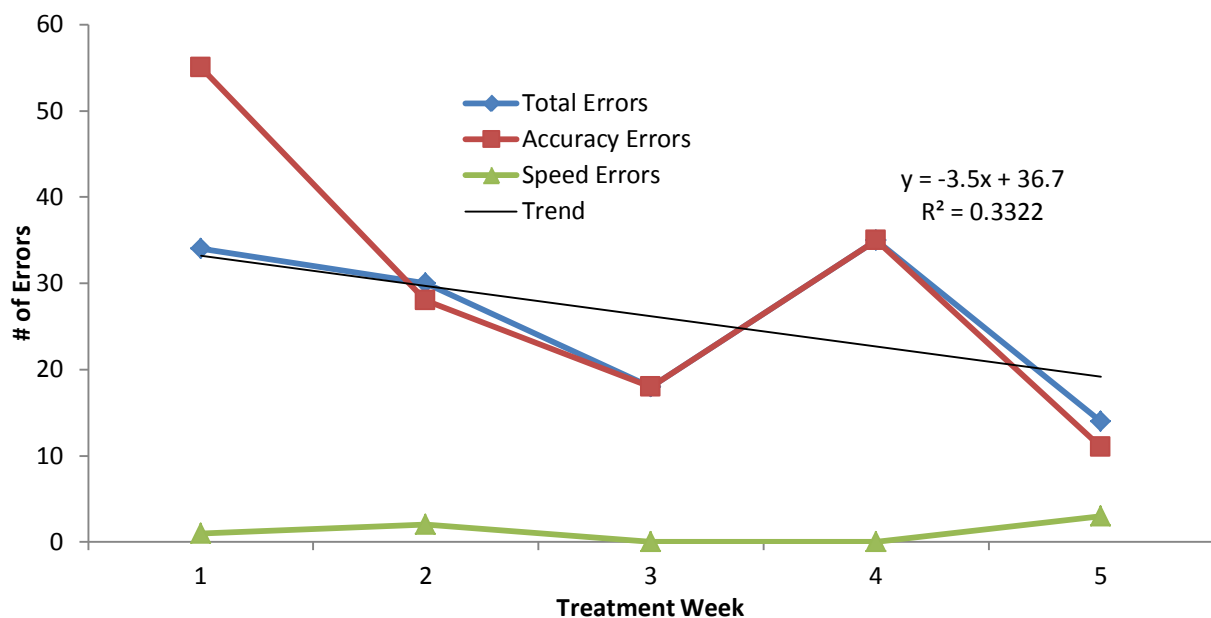
Figure 10.10. Participant 10's error data for the working memory treatment phase. (Decrease indicates improved performance on working memory training tasks.)
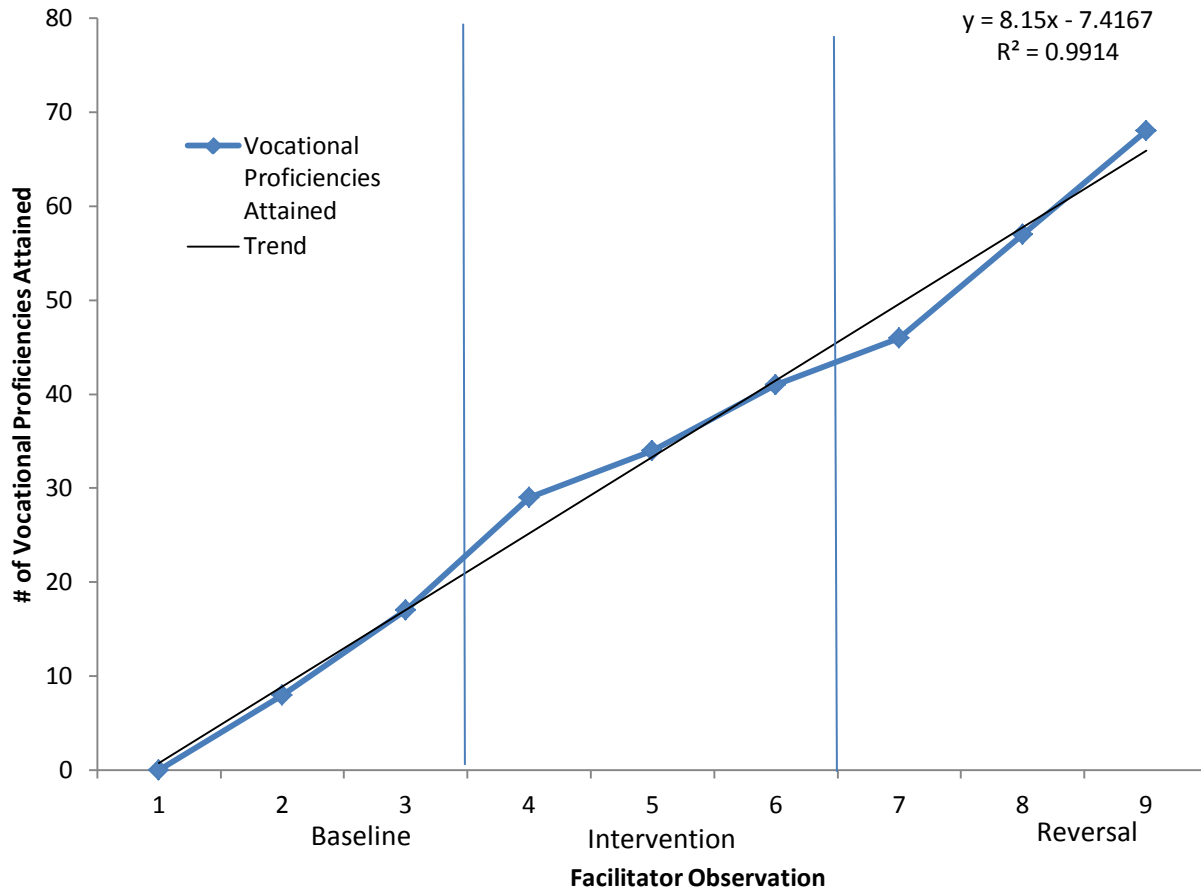
Figure 10.11. Participant 10's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TAR.)

Figure 10.11 represents the correct number of vocational proficiencies attained for each individual over the course of the baseline, treatment, and reversal phases. The number of vocational proficiencies attained should increase over time. Once a participant's evaluation indicates they have met a standard in vocational progress it will stay attained. Therefore visual analysis of levels between phases was conducted through examination of each phase's slope and mean.

Visual analysis of trend was also conducted by examining the least squares regression. The trend data, shown in Figure 10.11, indicated an upward movement through visual analysis.

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When calculating the least squares regression, a very strong relationship (R^2=.99) between the

phases was interpreted using Cohen's (1988) guidelines.

When analyzing the data across all three phases, participant 10's TABE scores indicated a

very small amount of variability. Kennedy (2005) defined variability as the extent to which

individual data points vary from the trend line.
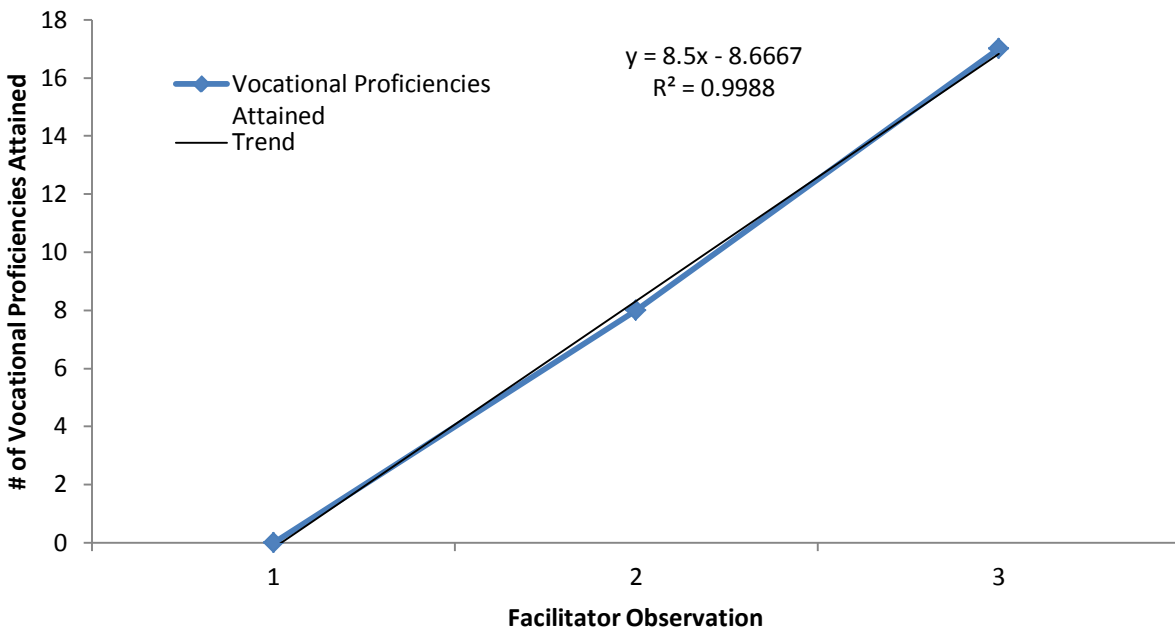
Figure 10.12. Participant 10's number of vocational skills attained through the TAR vocational

progress monitoring evaluation during the baseline phase.

For each individual phase the level, trend, and variability is analyzed. Figure 10.12

shows TAR data for the baseline phase. The data points of the baseline phase indicate a small

variability, an upward trend, a slope of 8.5, and a trend line with a large effect (R^2=.99). This

trend line indicated that participant 10's TAR scores were improving without intervention over

time.

Figure 10.13 shows TAR data for the intervention phase. The data points of the intervention phase indicated a low variability, an upward trend, a slope of 6, and a trend line with a large effect (R^2=.99). This trend line indicated that participant 10's TAR scores were still trending upward with intervention over time but with at a slightly lower rate.

Figure 10.14 shows TAR data for the reversal phase. The data for the reversal phase indicated a low variability, an upward trend, a slope of 11, and a trend line with a large effect (R^2=.99). This trend line indicated that participant 10's TAR scores were improving after the intervention at a slighter higher rate than baseline and intervention phases.

$$y = 6x + 22.667$$
$$R^2 = 0.9908$$
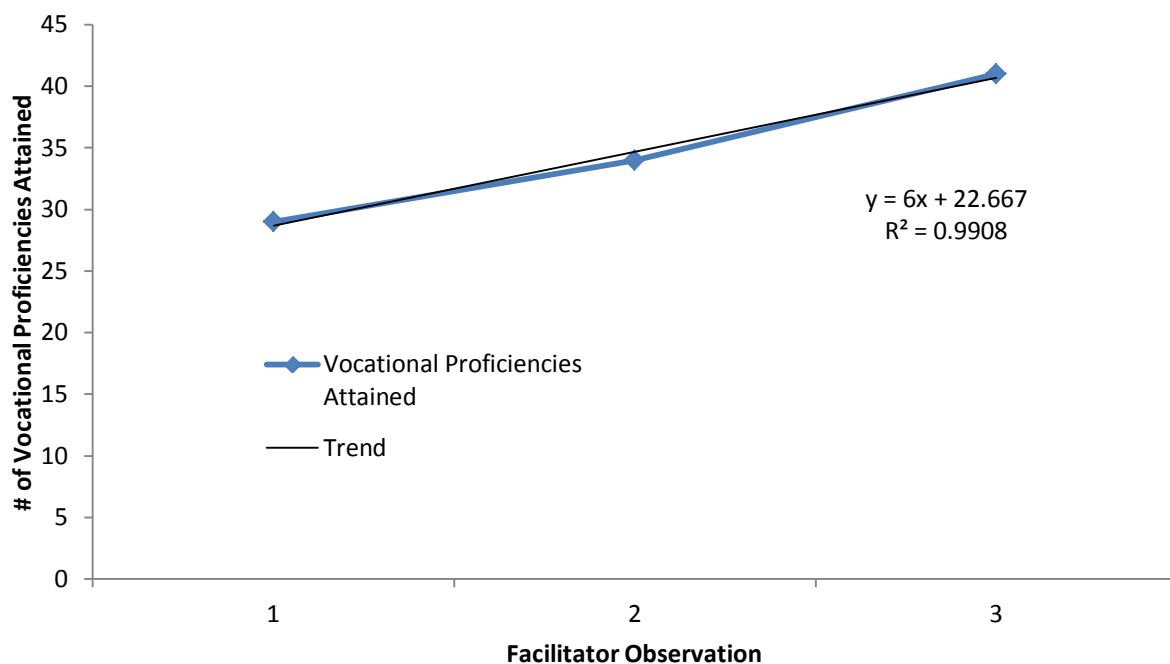
Figure 10.13. Participant 10's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the intervention phase.
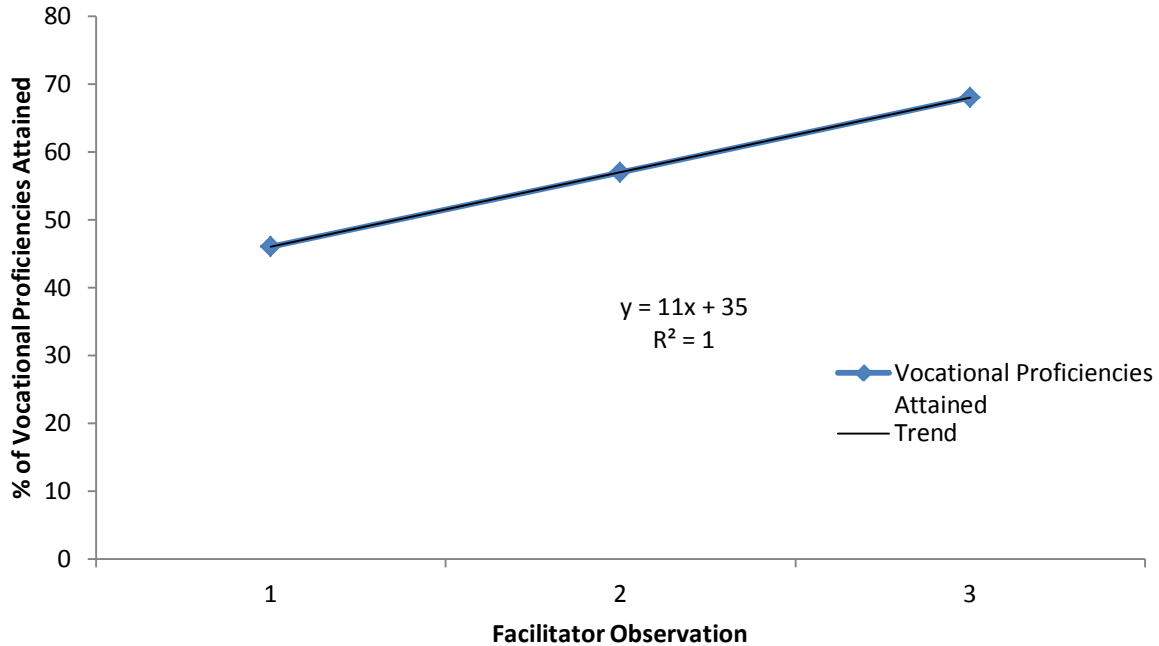
Figure 10.14. Participant 10's number of vocational skills attained through the TAR vocational progress monitoring evaluation during the reversal phase.

Participant 11

Participant 11was evaluated using the TABE test of numerical reasoning and observed using the TAR vocational progress monitoring survey. Participant 11 did not receive the five-week working memory training intervention. Scores for participant 11 were taken over the same time period as participants 1 through 10. Scores were broken up into baseline, intervention, and reversal phases. However, participant 11 did not receive any treatment and these phases are shown for comparison purposes.
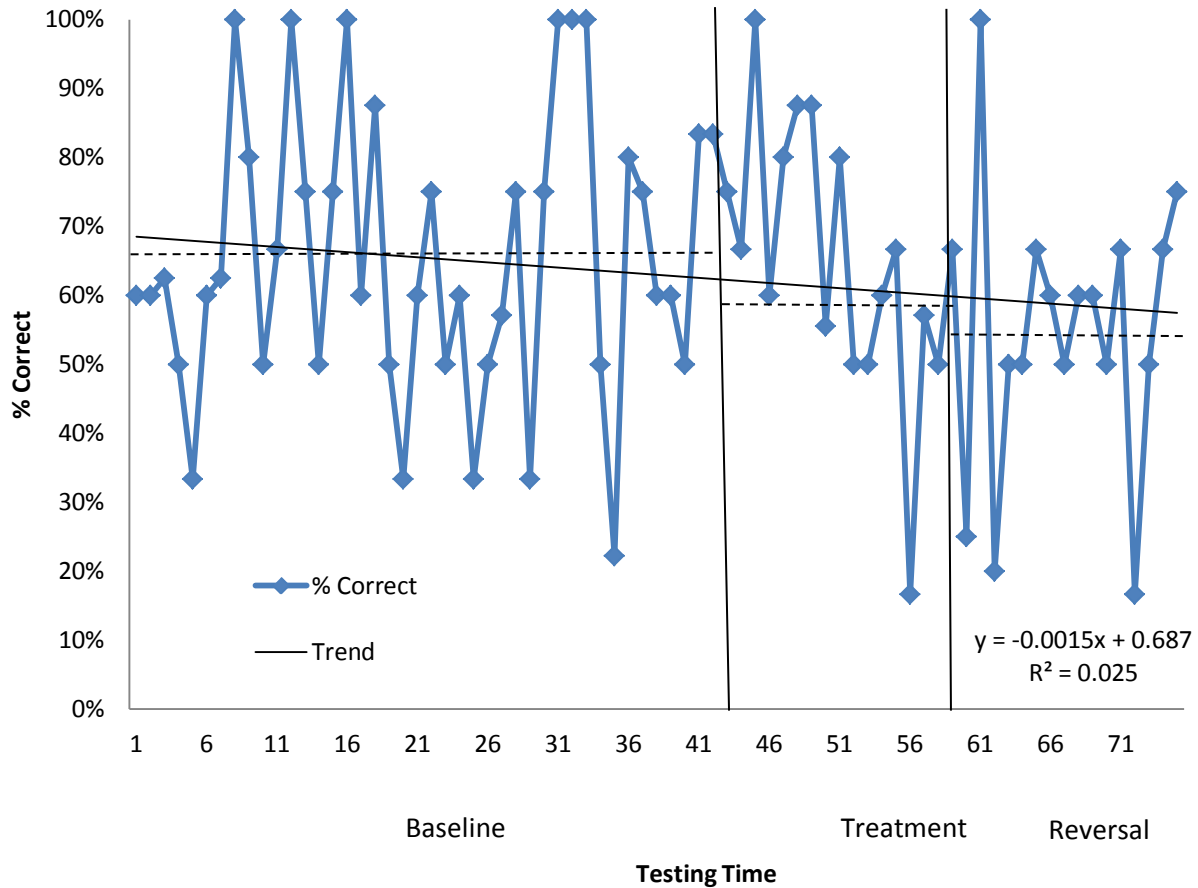
Figure 11.1. Participant 11's correctness on TABE tests of numerical reasoning during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

Figure 11.1 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 11.1 provides a graphical representation of the observed TABE scores for participant 11 across all phases of the study. The visual analysis of levels between phases was conducted through examination of each phase's mean. In Phase 1, the mean was 66%; in Phase 2, the mean was 59%, and in Phase 3, the mean was 56%.

When analyzing the data across all three phases, participant 11's TABE scores indicated a large amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation

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and variance was calculated to show the dispersion from the average. Participant 11's standard deviation for the entire experiment was 20.7% ($\sigma = .207$, $\sigma^2 = .043$).
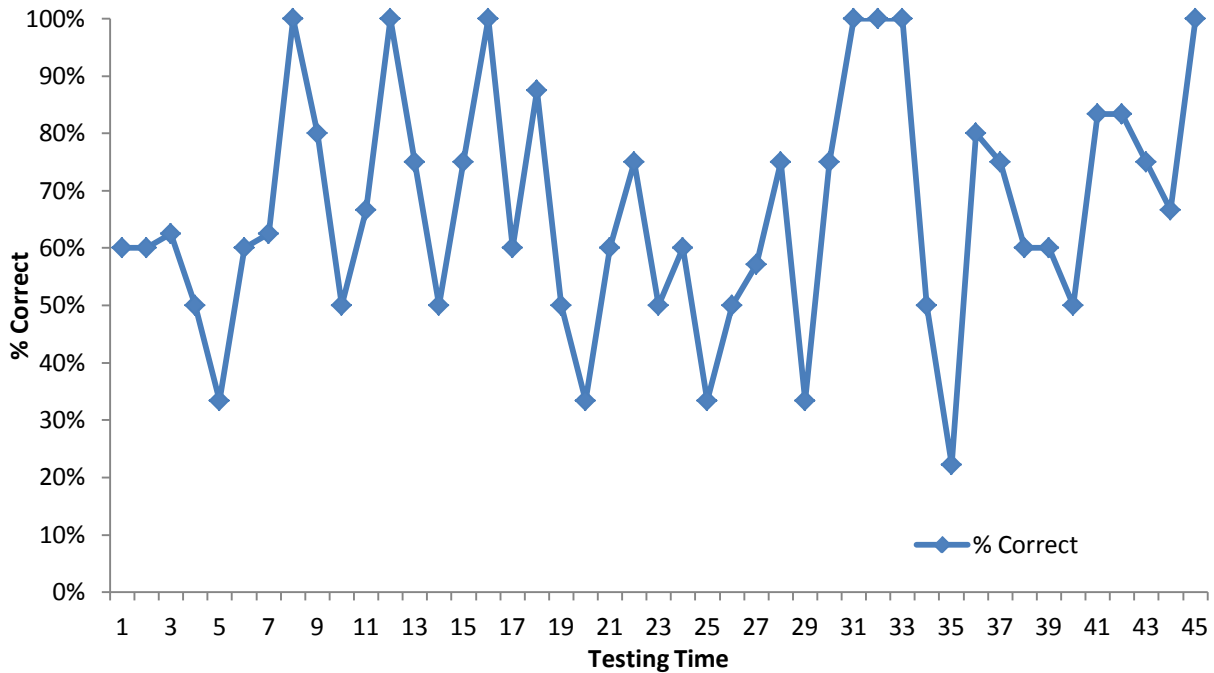
Figure 11.2. Participant 11's correctness trend for the TABE during the baseline phase.

For each individual phase the level and variability are analyzed. Figure 11.2 shows TABE data for the baseline phase. The data points of the baseline phase indicate a large variability and a mean of 66%. The standard deviation of the baseline phase was 20.6% ($\sigma = .206$, $\sigma^2 = .042$). Figure 11.3 shows TABE data for the intervention phase. The data points of the intervention phase indicated a large variability and a mean of 59%. The standard deviation of the intervention phase was 20.4% ($\sigma = .204$, $\sigma^2 = .041$).

Figure 11.4 shows TABE data for the reversal phase. The data for the reversal phase indicated a large variability and a mean of 56%. The standard deviation for the reversal phase

was 20.2% ($\sigma = .202,\ \sigma^2 = .040$).
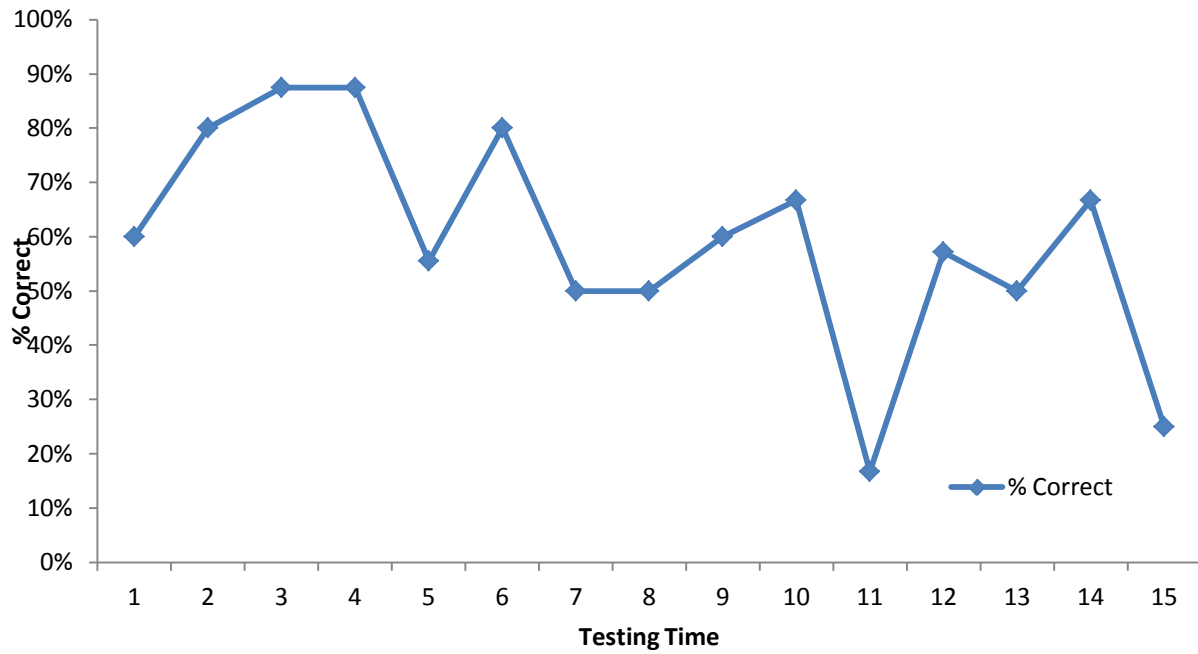
Figure 11.3. Participant 11's correctness trend for the TABE during the treatment phase.
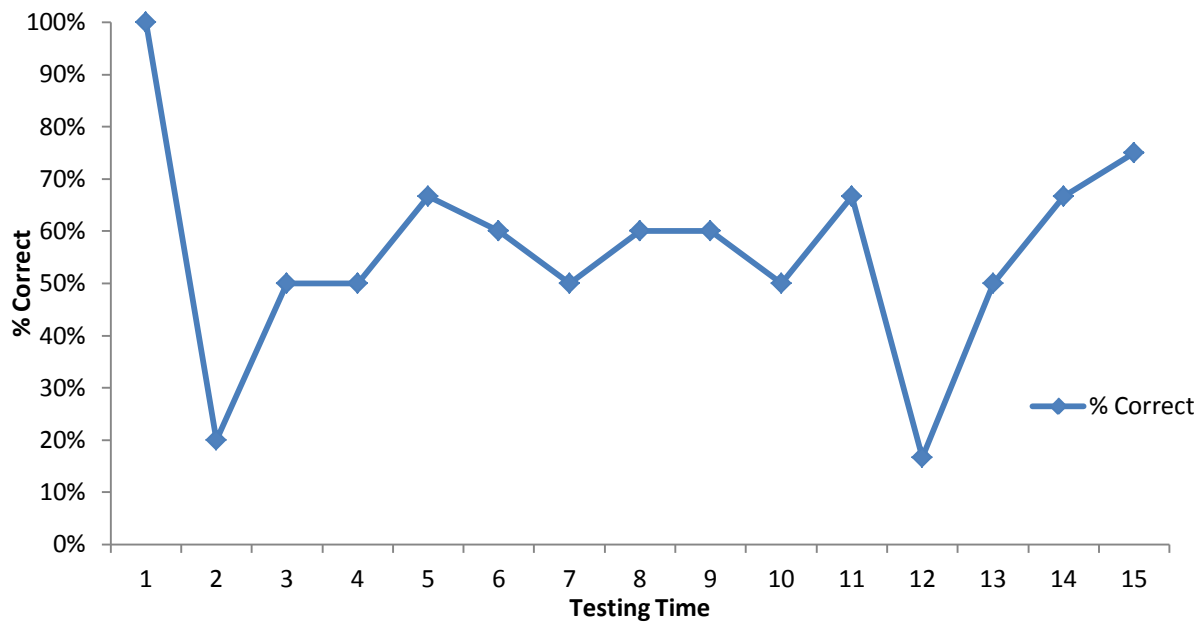
Figure 11.4. Participant 11's correctness trend for the TABE during the reversal phase.

Participant 12 was evaluated using the TABE test of numerical reasoning and observed using the TAR vocational progress monitoring survey. Participant 12 did not receive the five-week working memory training intervention. Scores for participant 12 were taken over the same time period as participants 1 through 10. Scores were broken up into baseline, intervention, and reversal phases. However, participant 12 did not receive any treatment and these phases are shown for comparison purposes.
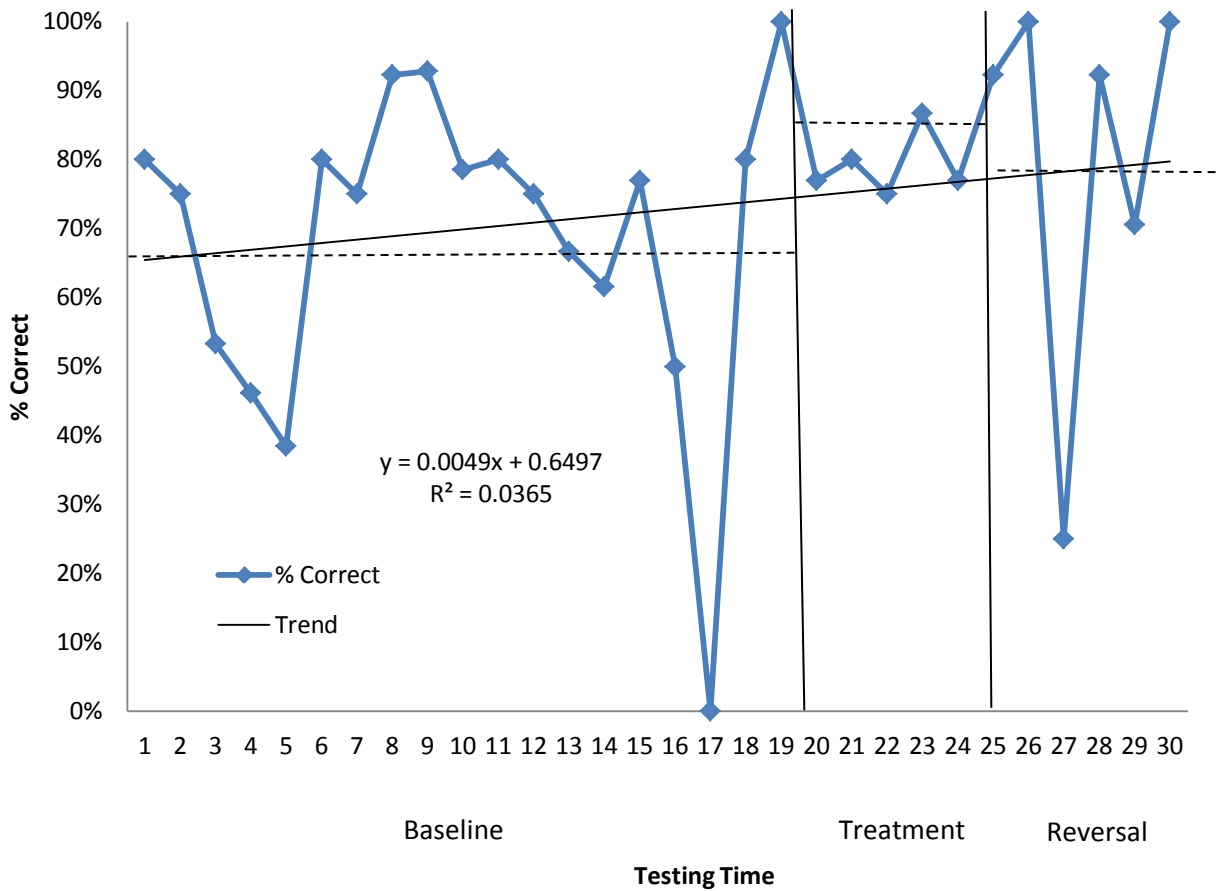
Figure 12.1. Participant 1's correctness on TABE tests of reading comprehension during the baseline, treatment, and reversal phases. (Increase indicates improved performance on TABE.)

Figure 12.1 represents the correct number of problems solved for each individual TABE measurement during the baseline, treatment, and reversal phases. Figure 12.1 provides a

graphical representation of the observed TABE scores for participant 12 across all phases of the study. In Phase 1, the mean was 69%; in Phase 2, the mean was 82%, and in Phase 3, the mean was 76%.

When analyzing the data across all three phases, participant 12's TABE scores indicated a moderate amount of variability. Kennedy (2005) defined variability as the extent to which individual data points vary from the trend line. In order to calculate the variability the standard deviation and variance was calculated to show the dispersion from the average. Participant 12's standard deviation for the entire experiment was 18.5% ($\sigma = .185$, $\sigma^2 = .034$).
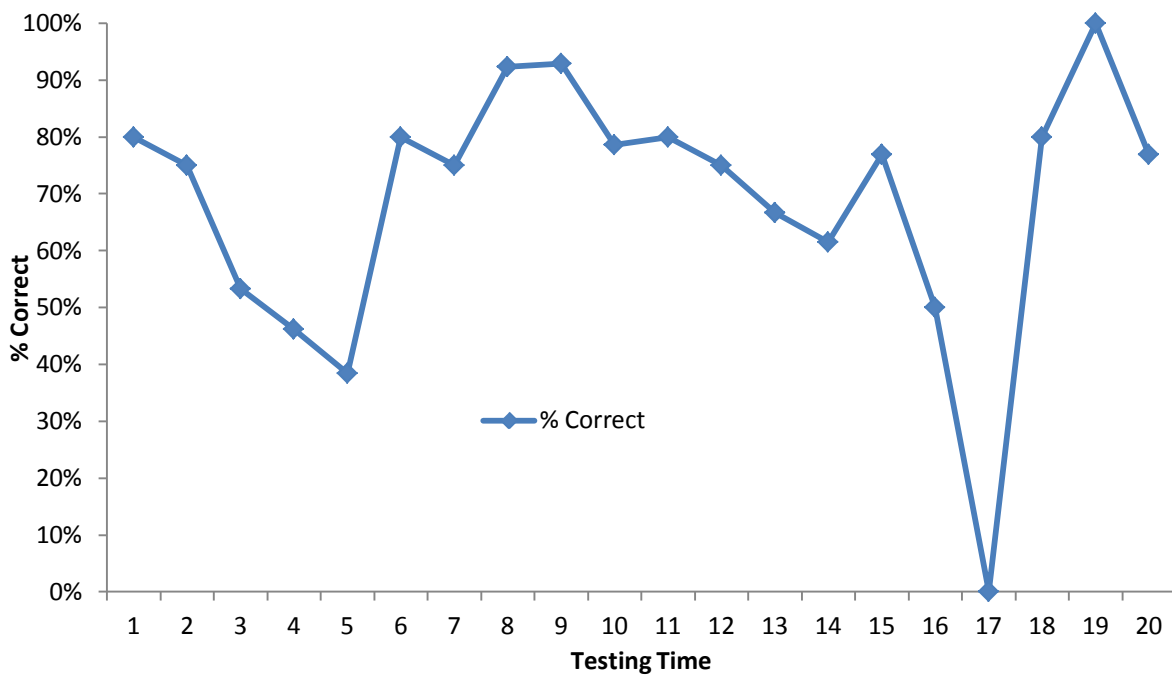
Figure 12.2. Participant 12's correctness trend for the TABE during the baseline phase.

For each individual phase the level and variability are analyzed. Figure 1.2 shows TABE data for the baseline phase. The data points of the baseline phase indicate a large variability and a mean of 69%. The standard deviation of the baseline phase was 22.6% ($\sigma = .226$, $\sigma^2 = .051$).

Figure 12.3 shows TABE data for the intervention phase. The data points of the intervention phase indicated a low variability and a mean of 82%. The standard deviation of the intervention phase was 7.2% ($\sigma = .072, \ \sigma^2 = .005$).

Figure 12.4 shows TABE data for the reversal phase. The data for the reversal phase indicated a large variability and a mean of 78%. The standard deviation for the reversal phase was 31.7% ($\sigma = .317, \ \sigma^2 = .100$).
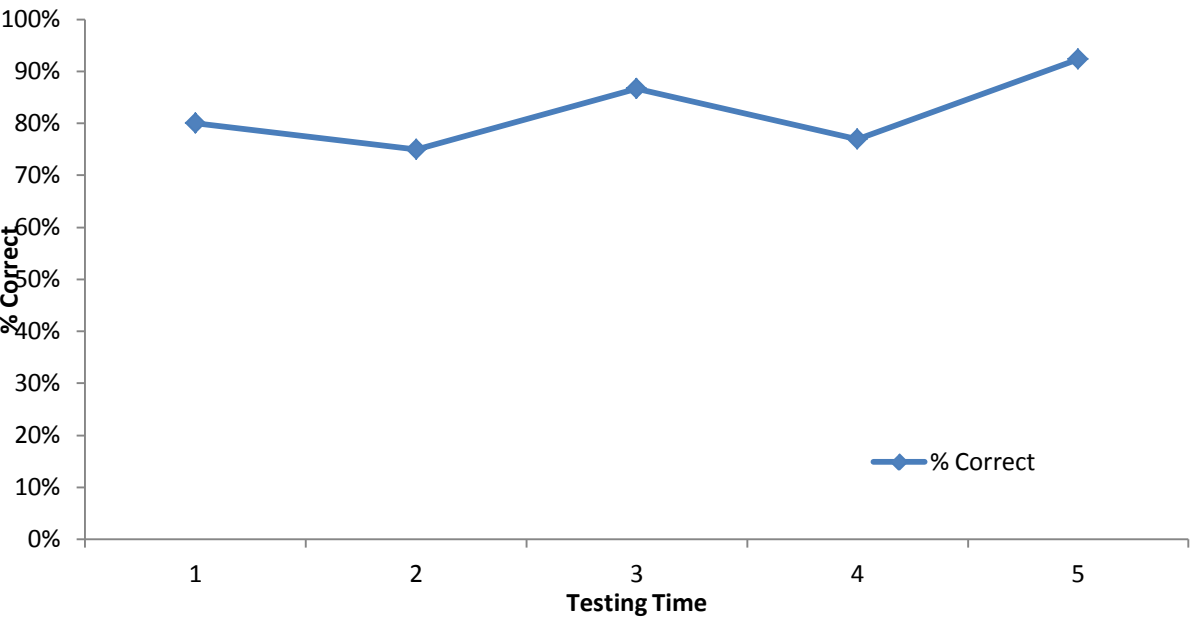
Figure 12.3. Participant 12's correctness trend for the TABE during the treatment phase.
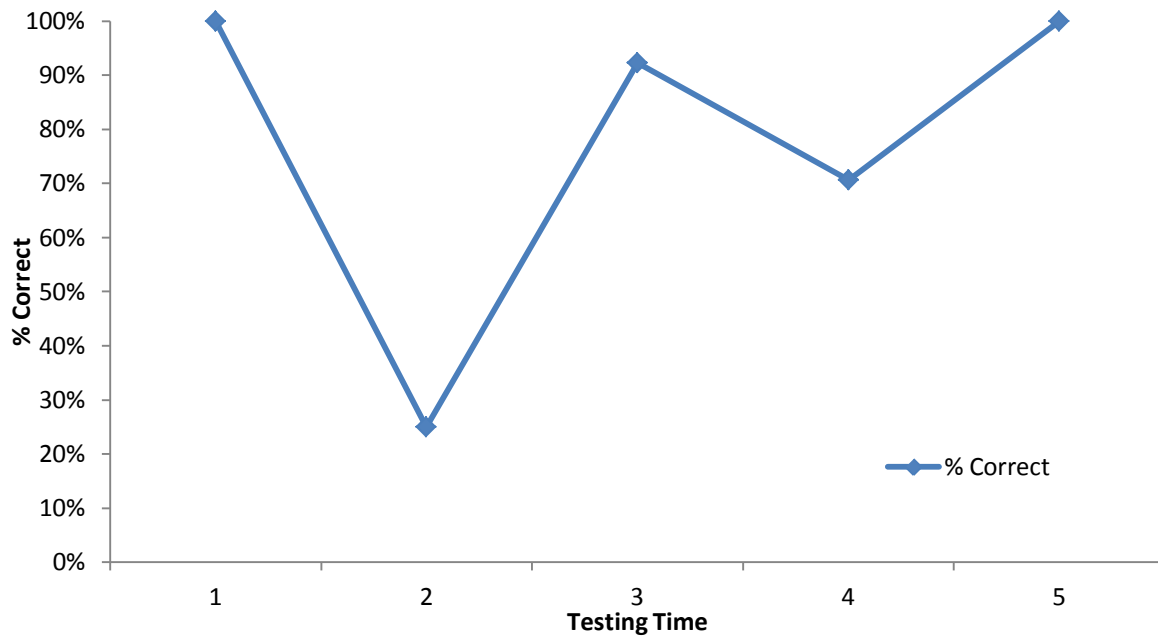
Figure 12.4. Participant 12's correctness trend for the TABE during the reversal phase.

Effect Size Analysis

Relationships between TABE scores and each experiment phase varied over each participant. Reading comprehension's relationship to time and each phase produced the strongest relationships among all dependent variables. Participant 1 showed a high effect size measurement indicating that scores improved through baseline and reversal. Participant 3's reading comprehension scores also showed strong effect size measurements indicating that the scores of reading comprehension benefited from the intervention. The same situation is true for participant 8 who saw strong effect size measurements throughout the experiment. Participant 10, the last of the four to be monitored for reading comprehension performance, saw a medium effect size measurement through each phase.

Seven out of the ten participants underwent TABE analysis for numerical comprehension. Throughout the experiment participants 2, 4, 6, 8, and 10 showed large effect size measurements indicating a strong relationship between scores and phases. Although visual analysis would

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indicate that levels of scores for all participants progressed through the study, participants 5 and 9 showed low effect size measurements in their TABE scores of numerical reasoning. This would indicate a weak relationship between scores and experimental phases.

Variability of Scores

For the TABE scores of reading comprehension and numerical reasoning, each phase of the study was broken down in terms of standard deviation and variance (σ and σ^2). Of the ten participants, nine showed descreases in score variance from baseline to intervention phases. Six out of those nine participants showed descreases in score variance again from intervention to reversal phases.Using the standard deviation squared (variance) to quantify variabilty, these gains in consistentcy of scores showed evidence that suggests that the intervention produced measureable gains to TABE testing scores. Participants 11 and 12,who received no treatment at all, did not show similar decreases in variability.

Table 1

Standard Deviation (σ) Across TABE Subtests Percent Correct

Participant	All Phases	Baseline	Treatment	Reversal	Change in σ
Participant 1 - Reading	.185	.210	.064	.085	-.125
Participant 2 - Math	.239	.245	.183	.129	-.116
Participant 3 - Reading	.171	.162	.076	.074	-.088
Participant 4 - Math	.229	.185	.284	.214	+.029
Participant 5 - Math	.249	.252	.198	.206	-.046
Participant 6 - Math	.241	.189	.115	.112	-.077
Participant 7 - Math	.222	.199	.137	.093	-.106
Participant 8 - Math	.267	.255	.207	.176	-.079
Participant 8 - Reading	.230	.185	.050	.229	+.044
Participant 9 - Math	.154	.152	.133	.115	-.037
Participant 10 - Math	.265	.282	.151	.023	-.259
Participant 10 - Reading	.168	.193	.023	.097	-.096
Participant 11 – Math (No Treatment)	.202	.206	.204	.202	-.004
Participant 12 – Reading (No Treatment)	.185	.226	.072	.317	+.091

Table 2

Variance (σ^2) Across TABE Subtests Percent Correct

Participant	All Phases	Baseline	Treatment	Reversal	Change in σ^2
Participant 1 - Reading	.034	.044	.004	.007	-.037
Participant 2 - Math	.057	.057	.034	.016	-.041
Participant 3 - Reading	.029	.026	.006	.006	-.020
Participant 4 - Math	.052	.034	.080	.046	+.012
Participant 5 - Math	.062	.064	.039	.042	-.022
Participant 6 - Math	.058	.035	.013	.013	-.022
Participant 7 - Math	.049	.040	.019	.009	-.031
Participant 8 - Math	.071	.065	.043	.031	-.034
Participant 8 - Reading	.053	.034	.003	.052	+.018
Participant 9 - Math	.024	.023	.018	.013	-.010
Participant 10 - Math	.070	.080	.205	.042	-.038
Participant 10 - Reading	.028	.037	.001	.009	-.028
Participant 11 – Math (No Treatment)	.043	.042	.041	.040	-.002
Participant 12 – Reading (No Treatment)	.034	.051	.005	.100	+.049

Summary of Visual Analysis

The evaluation of working memory training on participant scores of reading comprehension, numerical reasoning, and vocational progress produced varied results. In regards to TABE scores of reading comprehension, participants three and ten demonstrated gains in means across all three phases. For participants one and eight, the percentage of correct items increased during the intervention phase, but regressed during the reversal phase.

In regards to TABE scores of numerical comprehension, participants two, four, six, eight, nine, and ten demonstrated gains in means across all three phases. For participant five, the percentage of correct items increased during the intervention phase, but regressed during the reversal phase.

In regards to the TAR vocational progress evaluation, participant six demonstrated gains in the rate of attainment across all three phases. For participants three, four, five, seven, eight, and nine the rate of skills attainment increased during the intervention phase, but regressed during the reversal phase. For participants one, two, and ten, there was no gain in the rate of vocational skill attainment during intervention but there were gains at the reversal phase. All ten participants in the study were evaluated using the TAR.

CHAPTER FIVE

DISCUSSION

The purpose of this study was to analyze working memory training's enhancement effects and its ability in transferring training task performance to numerical reasoning, reading comprehension, and vocational progress within the realm of standardized testing and facilitator observations. If individuals can actively and successfully train to expand working memory capacity then is numerical reasoning transferred and in what ways can we quantify dynamic changes to numerical reasoning? And in that same respect, if individuals can actively and successfully train to expand working memory capacity then is reading comprehension transferred and in what ways can we quantify dynamic changes to reading comprehension? The study aims to discover the extent to which working memory training impacts participants through formal assessment processes, including measures of academic and vocational progress.

The results of the research demonstrated that measureable gains in performance of reading comprehension and numerical reasoning can be obtained during an intervention of working memory training task exercises. However, retention of these gains is varied among participants and limits to the single case design do not allow for generalizability or rule out the occurrence of maturation of scores. In addition, the research did not show evidence of measureable gains in vocational progress during or after the same intervention of working

memory training task exercises. Despite these limitations, the study showed evidence to the potential benefit of working memory training.

Overall Summary of Data

Visual inspection of the data for all participants showed variations in the amount of improved performance for the TABE and TAR scores. Each participant who was monitored for performance in reading comprehension showed gains in scores during the five week working memory training phase. At the height of the training intervention measureable gains in reading comprehension were apparent. In terms of numerical reasoning participants all demonstrated gains across the intervention and reversal phases. Each participant who was monitored for performance in numerical reasoning showed gains in scores during the five week working memory training phases. Based on the increases between means of each phase, visual analysis of numerical reasoning and reading comprehension scores showed the benefit of working memory training.

For scores of vocational progress the rate of attainment was monitored as opposed to an assessed score. In terms of visual analysis the predominant technique used was careful analysis of the trend. This was due to the fact that the number of vocational skills attained over time naturally increased as a participant showed competency. In this respect, participants did not show an increase in the rate of attainment across the intervention and reversal phases. Measureable gains in vocational progress via the TAR surveys were not as prevalent compared to gains in both TABE assessments.

Using a value of standard deviation, each phase of the study was analyzed for variability of scores. It was apparent during the baseline phases that particiapnts had highly variable scores for each TABE subtest in reading comprehension and numerical reasoning. As a result of the

treatment, values of variability decreased as means increased. Measureable improvements of scoring consistency complimented improvements in reading comprehension and numerical reasoning. The decreases in standard deviation and variance in the treatment and reversal phases provides evidence of participant transfer from working memory training tasks by production of more precise and consistent scores. Participants showed not only an increase in the levels (means) of scores throughout each phase but attained scores there were more precise (less variable) measurements of ability.

The effect size analysis applied to the data consisted of a regression based method. The calculation of the R^2 value is a measure of the proportion of variance shared by the two variables of correctness and TABE subtests. Participants of the study showed strong relationships between the independent and dependent variables indicating evidence of measureable gains to scores as a result of the experimental treatment. However, due to the nature of the single case design maturation of scores cannot be ruled out as a primary causal factor.

Implications for Practice

Over time, participants of the study became increasing comfortable with the working memory training exercises. Not only did scores for each training task increase over time but the amount of accuracy and speed errors decreased. Each training session was completed on a personal computer and participants were able to complete the training within the 50-60 minute timeframe. As experience with the training increased the need for facilitation decreased. The training itself was practical for the school facility and appeared to have potential as an ongoing resource for students. Participants became increasingly independent with each successive training session. Participants were eager to outperform previous scores and felt accomplished by the end of the five week training period.

Participants were made aware at the beginning of training that the working memory tasks were designed to be difficult and present a challenge. It was also made aware to participants that perfect scores on tasks were highly unlikely and that focus should be placed on performing better over time. Participants appeared to be motivated by the immediate feedback but it was also apparent through numerous session scores that there were times of frustration with large accuracy and speed errors.

Working memory training tasks possess a high degree of potential for being an outlet for small groups of students to focus attention on comprehension and reasoning exercises. However, these same exercises may require the assistance of a facilitator to alleviate any potential frustration and remind students that personal progress over time should be the primary focus.

The ability for executive cognitive functions of working memory to expand through intensive training has vast potential to benefit our everyday decision making as well as our information processing skills. Adult education facilities that use scores from comprehension and reasoning tests in order to place individuals for future lines of work can use cognitive training tasks as a way to focus individual attention in testing situations. If participants can use training to control central executive functioning then execution of their abilities will yield higher scores and potentially better cognitive results.

Limitations

The single case design method requires researchers to make a clear description of research methodology in order to allow for replication (Kazdin, 1982). The design of this study itself creates its own limitations and because of the design, in order to allow for generalizability, there is an increased need for replication. The results of the study must be viewed in terms of the

individual participant cases that were involved. The study also had a relatively small sample size and because of that any generalizability to other potential participants is questionable.

Also, in regards to the single case design, there are intrinsic problems with interpretation because the primary technique for data analysis is visual. Conclusions drawn from visual analysis are not as clear as many forms of statistical analysis. Certain individual patterns in data are difficult to accurately interpret and may be a result of extraneous events or unrelated factors. In addition, the single case study is designed to test applied settings and yield casual findings.

In regards to the study methodology itself, the need for a consistent training schedule decreased the amount of participants in the study. Five participants who were absent on numerous days were subsequently removed from the study. These participants who were unable to keep up with the training due to absenteeism were unable to complete the training. In the event of replication of the study, participants should clearly be made aware of the five week commitment to the training itself.

Recommendations for Future Research

Reliability of the results of the study depends on the replication of data. Since single case designs deal with small sample sizes, a straight forward and easily accessible methodology will help future research to better understand the relationships involved in working memory training through a meta-analysis of data.

 In a scenario where study participants are undergoing similar trainings, a more detailed analysis of vocational progress may benefit a researcher. Simple surveys of vocational attainment may not be the best indicator of progress because it is not an in depth critique of skills similar to that of a standardized exam of reading or math. A researcher would benefit from a detailed score based system of vocational progress to monitor potential gains.

It is of significant value in education to study the behavior of working memory capacity because of the strong relationship between a working memory measure and assessed measurement of ability in reading comprehension and numerical reasoning. More importantly, individuals with deficits in attention, academic achievement, and cognitive ability can potentially find benefit with an increase working memory capacity.

Summary

In regards to the research questions, both reading comprehension and numerical reasoning saw transferable gains with working memory training treatments. There was less evidence to support a relationship in gains with vocational progress. This may have been a result of the survey based method of collecting data that was unlike the assessment of correctness found within the TABE scores. Because of the small sample size and individualized results the use of a single case experimental design provided much information that helped to target behaviors of participants.

A successful intervention yielded a decrease of the variability of testing scores and an increase in the means of subtests over time. The findings provide evidence that an intensive training schedule of working memory tasks where task performance increases over time will yield a pattern of consistent performance on tests of reading comprehension and numerical reasoning.

Recent studies have investigated how working memory training tasks show transfer to improvement in cognitive function beyond specific training tasks (Schweizer, Hampshire, & Dalgleish, 2011). Dual task working memory trainings have been found to engage executive processes associated with working memory and show relationships to gains in fluid intelligence measurements. Study findings suggest that individuals can learn and expand working memory

capacity through training on a task that improves executive control of affective material. When participants become better at engaging with goal-relevant tasks they are able to ignore highly emotional material that is not pertinent or distracting from the target task. This will allow them to perform better on assessments of reasoning and comprehension. Through dual task treatment the current study has added evidence to support the construct of working memory training by showing relationships between increased capacity and TABE subtest scores of reading comprehension and numerical reasoning.

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APPENDIX A

SUBJECT INFORMATION AND INFORMED CONSENT

SUBJECT INFORMATION AND INFORMED CONSENT

Title: Working Memory Training and The Effect on Standardized Testing and Work Performance

Project Director(s):
David Johnson, Graduate Assistant, Curriculum & Instruction, ED 330
Faculty Supervisor: Fletcher Brown, Associate Professor of Science and Environmental
Education, Curriculum & Instruction, ED 106, 406-243-5287

Special instructions:

This consent form may contain words that are new to you. If you read any words that are not clear to you, please ask the person who gave you this form to explain them to you.

Purpose:

The purpose of this research study is to explore how working memory training affects Test of Adult Basic Education (TABE) scores and subjective performance on job skills training.

Procedures:

You will be asked to anonymously submit scoring data from recent working memory training tasks completed at your education facility. In addition, you will be asked to anonymously submit scoring data from recent Tests of Adult Basic Education and counselor evaluations of work performance. Your data will never be tied to your name and all information will be sent anonymously. This data will be used in a study to evaluate the effectiveness of working memory training.

For your participation in this study you will receive a gift card in the amount of ten dollars.

Risks/Discomforts:

You may decline to submit your information and you may stop participation in the study at any time and for any reason. Data received from you will be destroyed after completion of the study.

Benefits:

There is no promise that you will receive any benefit from taking part in this study.

Confidentiality:

Your data will be kept confidential and will not be released without your consent except as required by law.

Only the researcher and faculty supervisor will have access to the files. Your identity will be kept private.

By participating in this study, you acknowledge that your records are protected under FERPA regulations and you are giving explicit permission for your data to be used for the specific project described.

The data will be stored in a locked file cabinet.

Your signed consent form will be stored in a cabinet separate from the data.

Voluntary Participation/Withdrawal:
Your decision to take part in this research study is entirely voluntary.

You may leave the study for any reason.

Questions:
If you have any questions regarding this study, you may contact the researcher at david.johnson@umontana.edu.

If you have any questions regarding your rights as a research subject, you may contact the Chair of the IRB through The University of Montana Research Office at 406-243-6670.

Statement of Consent:
I have read the above description of this research study. I have been informed of the risks and benefits involved, and all my questions have been answered to my satisfaction. Furthermore, I have been assured that any future questions I may have will also be answered by a member of the research team. I voluntarily agree to take part in this study. I understand I will receive a copy of this consent form.

_____
Printed Name of Subject

_____   _____
Subject's Signature   Date

APPENDIX B

FACILITATOR GUIDELINES

Working Memory Training - Facilitator Guidelines

1. Do not begin training until each participant is ready.
2. The training is designed to be difficult and require the full attention of participants.
3. The training will be ineffective if participants are unwilling to try and devote full attention to the training.
4. Completing each task with effort is much more important than getting every problem right. For some tasks it is nearly impossible to get all answers correct.
5. Once a training task is started it cannot be stopped until completed.
6. Each training task has a practice round and a full training round. They will both take between 10-25 minutes to complete.
7. Each training day will have 2-3 training tasks and last about 50-60 minutes. (Faster after practice)
8. Please assist during the practice round for each training task. The training is not timed but may require quick responses.

Training Schedule (3 times a week for 5 weeks)

	Day 1	Day 2	Day 3
Week 1	Symmetry Task Reading Task Operations Task	Listening Task Operations Task Reading Task	Symmetry Task N Back Task
Week 2	Listening Task Operations Task Symmetry Task	Reading Task Operations Task Listening Task	Symmetry Task N Back Task
Week 3	Symmetry Task Reading Task Operations Task	Listening Task Operations Task Reading Task	Symmetry Task N Back Task
Week 4	Listening Task Operations Task Symmetry Task	Reading Task Operations Task Listening Task	Symmetry Task N Back Task
Week 5	Listening Task N Back Task	Operations Task N Back Task	Reading Task Listening Task Operations Task

Note: The N Back Task is very difficult and requires more practice to master. Increased performance on the N Back Task deserves commendation.

APPENDIX C

TRAPPER CREEK LETTER TO IRB

United States
Department of
Agriculture

Forest
Service

Trapper Creek JCCCC

5139 West Fork Road
Darby, MT 59820
406-821-3286

Date: September 11, 2013

Paula Baker
University of Montana IRB
(406) 243-6672

RE: Working Memory Training

Paula,

     David Johnson has been working with me through the University of Montana for several months. He and I came to an agreement to use students at Trapper Creek Job Corps for purposes of research with working memory. Students were selected from our program based on predetermined criteria, and these students were identified with a random number in order for Mr. Johnson to assign them to control and treatment groups. This has ensured that all data during the process is completely confidential and anonymous. The subjects in this research have agreed to these conditions and engaged in the research willingly.

Please do not hesitate to contact me with any questions or concerns.

Best,

/s/ Jesse Casterson

Jesse Casterson, MA
Principal Teacher, Disability Coordinator
Trapper Creek Job Corps
jcasterson@fs.fed.us
Phone: (406) 821-2101
Fax: (406) 821-3290

APPENDIX D

WORKING MEMORY TRAINING EXPERIEMENT FLOWCHART

Working Memory Training Experimental Flowchart

Baseline Measurement (Archival Data): TABE Testing
(Reading and/or Math), Vocational Progress Monitoring

Several Dates From at least 90 Days Before Training

↓

Baseline Measurement: TABE Test (Reading and/or Math), Vocational Progress Monitoring

Within 30 Days Before Training

↓

Training Week #1: Dual N Back Task, Listening Span,
Operational Span, Reading Span, Symmetry Span

Training Week #2: Dual N Back Task, Listening Span,
Operational Span, Reading Span, Symmetry Span

Training Week #3: Dual N Back Task, Listening Span,
Operational Span, Reading Span, Symmetry Span

Training Week #4: Dual N Back Task, Listening Span,
Operational Span, Reading Span, Symmetry Span

Training Week #5: Dual N Back Task, Listening Span,
Operational Span, Reading Span, Symmetry Span

Treatment Measurement:
TABE Scores (Reading
and/or Math), Vocational
Progress Monitoring

Within Treatment Time

↓

Follow Up Measurement: TABE Scores (Reading and/or Math), Vocational Progress Monitoring

30-45 Days After Last Training